Idaho National Engineering and Environmental Laboratory

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Raw Data Report and Meeting Record from the Vadose Zone/Groundwater Uncertainties Prioritization Meeting

April 2 & 3, 2002

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Prepared By
William "Buck" West

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Idaho National Engineering and Environmental Laboratory
Idaho Falls, Idaho 83415

ABSTRACT

The purpose of this document is to document and present the results of a Value Engineering Session held in Idaho Falls, Idaho on April 2 & 3, 2002 to prioritize vadose zone and groundwater uncertainties. These uncertainties were developed as part of the INEEL Vadose Zone/Groundwater Roadmapping task of the Water Integration Project. The uncertainties were developed over a two-year period by scientists and engineers knowledgeable in the areas of geosciences, flow and transport modeling, source term issues, and surface and groundwater issues. These uncertainties represent gaps in knowledge and capabilities for the vadose zone and groundwater at the INEEL. There were 25 uncertainties developed by utilizing the uncertainties from the document,*"Uncertain Predictions of Contaminant Behavior at INEEL: A Roadmap for Addressing Current Limitations through Vadose Zone Studies, INEEL/EXT-2001-552, Draft, September 2001"*, and from an uncertainties validation meeting held in March 2002.

Twenty-four people participated in the Value Engineer Session to prioritize the uncertainties. These twenty-four represented public stakeholders, federal and state regulators, INEEL State Oversight, the United States Geological Survey, DOE Headquarters, DOE-ID, and BBWI. They had a wide range of backgrounds including concerned public, INEEL Operations, geoscience research, flow and transport modeling, geochemistry, contaminant experts, applied geosciences, agriculture, academia, and project management. These 25 people spent the two days discussing the uncertainties, developing criteria to be used in the prioritization, and prioritizing the uncertainties. All raw data and the happenings of the two days are presented in this document. The results of this ranking will be used to develop science strategies for integrating research and technology development and long term monitoring projects at the INEEL to more effectively achieve programmatic goals.

CONTENTS

Executive Summary

Dates and Times

April 2, 2002, from 08:00 to 17:00 hours, and April 3, 2002, from 08:00 to 14:00 hours.

Location

West Coast Hotel Yellowstone/Teton Conference room, Idaho Falls, ID.

Objectives

1. Identify, define, and weight 3-5 criteria for prioritizing technical uncertainties in predictions of contaminate behavior in the Vadose Zone/Groundwater at the INEEL.

2. Using the criteria, prioritize technical uncertainties identified in the Uncertain Predictions of Contaminate Behavior at INEEL.

Attendees

NAME	REPRESENTING	PHONE	E-MAIL
Amos, Melvin IV	DOE-ID	526-4030	Amosmd@id.doe.gov
Becker, Bruce	INEEL	526-0659	Hbb@inel.gov
Brailsford, Beatrice	Snake River Alliance	234-4782	Srabb@earthlink.net
Burns, Doug	INEEL	526-4324	Deb4@inel.gov
Frederick, Dave	INEEL Oversight	528-2614	Dfreder:@deq.state.id.us
Hull, Larry	INEEL	526-1922	Hulllc@inel.gov
Kauffman, Richard M.	DOE-ID	526-7177	Kauffmrm@inel.gov
Knobel, LeRoy	USGS	526-2158	Llknobel@usgs.gov
Magnuson, Swen	INEEL	526-8618	Smm@inel.gov
McCarthy, James	INEEL	526-8319	Ja7@inel.gov
McLing, Travis	INEEL	526-7269	Tm1@inel.gov
Nuckols, E. B.	DOE Head Quarters	301-903-2805	Ernest.nuckols@em.doe.gov
Orr, Brennon	USGS	526-2157	Brorr@usge.gov
Perry, Jeffrey N.	DOE-ID	526-4570	Perryjn@inel.gov
Pierre, Wayne	EPA	206-553-7261	Pierre.wayne@epa.gov
Rydalch, Dave	Citizen Advisory Board	351-1237	Dave@rydlach.com
Smith, Dick	INEEL	526-9896	Rps3@inel.gov
Smith, Robert W.	UI/INRA	282-7954	Smithbob@uidaho.edu
Street, Leah	INEEL	526-9535	Lst@inel.gov
Tanner, John	Coalition 21	529-5605	Pust@srv.net
Weingartner, Brooks	DOE-ID	526-1366	Weingacb@inel.gov
Winter, Gerry	Idaho DEQ	373-0402	Gwinter@deq.state.id.us
Wright, Mike	INEEL	526-3315	Wrigpm@inel.gov
Yonk, Alan	INEEL	526-5828	Yonkak@inel.gov

Meeting Results

The group was asked if all the uncertainties listed were, in fact, true uncertainties or assumptions or needs for the program. The group identified the following uncertainty as not a true uncertainty:

- Nonlinear governing equations for multiphase flow requires iterative solution schemes. (technical limitation)

Five other uncertainties received mixed results that might indicate they are not true uncertainties. Those questionable uncertainties are:

- Quantifying the relative contributions to non-ideal behavior will require advances in detection and discriminatory analysis capabilities.
- Temporally varying fluid saturations and pressures, precipitation, evapotranspiration, temperature, barometric pressure, etc., are collected sporadically.
- Geophysical logs and the tools for analyzing basalt logs are inadequate for conceptual model development. (New uncertainty)
- Available field data are of insufficient quality and quantity for use in predictive simulation.

The group identified four criteria to use in the prioritization of the twenty-five Vadose Zone/Groundwater uncertainties. Those four criteria are:

1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (weight 0.589)
2. Return on investment. (weight 0.111)
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (weight 0.060)
4. Is it practical to address the uncertainty. (weight 0.240)

The group rated, on a scale of 1-5, the uncertainties against the four weighted criteria (see above). The prioritized order of the uncertainties based on the weighted total of all criteria is as follows:

- 9.[1]Mechanisms and parameters describing adsorption of contaminants onto INEEL materials have not been adequately developed or measured. (score 15.85[2])
- 5.Knowledge of stratigraphic and structural controls on flow patterns in the vadose zone and the aquifer is limited. (New uncertainty) (score 15.49)
- 1.Available field data are of insufficient quality and quantity for use in predictive simulation. (score 15.25)
- 2.Conceptual Models are often inadequate for prediction because they do not incorporated necessary physical and biogeochemical processes. (score 14.88)
- 13.Chemistry of the near-field environment (e.g. the oxidation-reduction potential and solubility effects) may significantly affect the release and the rate of migration. (Original 7 & 11 combined) (score 14.77)
- 7.Flow direction and temporal behavior in the aquifer is limited. (New uncertainty) (score 14.43)
- 10.Conditions leading to facilitated transport are unknown. (score 14.19)
- 20.Preferred pathways are not detected or monitored, and there is relatively little information available. (score 14.12)
- 15.Contaminant Inventory Uncertainties (replaces original #14) (score 14.02)
- 4.Various sources of uncertainty and their relative impact on the predictability of transport is unknown and currently unqualified. (score 13.90)
- 17.Temporally varying fluid saturations and pressures, precipitation, evapotranspiration, temperature, barometric pressure, etc., are collected sporadically. (score 13.74)
- 6.Limited information is available on possible vertical transport in the aquifer. (score 13.57)
- 14.Temporal behavior of the containers and waste forms relative to contaminant release is unknown. (score 13.48)

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[1] The number preceeding the uncertainity refers to it's original location on the list of uncertainities.

[2] Total weighted score for all four criteria.

- 23.Laboratory-determined properties have not been related to field-scale values and conditions. (score 13.14)
- 12.Near-field hydraulic conditions and their influence on contaminant release and migration are unknown. (score 12.72)
- 19.Relationships between extracted concentrations, small volume measurements of vadose zone parameters, biologic indicators, and state variables to those of the larger subsurface environment are unknown. (Combination of original #s 16,22, & 23) (score 12.37)
- 16.The extent to which interactions between phases (vapor, liquid, organic interactions, etc.) affects transport is unknown. (New uncertainty) (score 12.21)
- 11.Microbial effects on contaminant degradation transport rates, and mechanisms in both the vadose zone and the aquifer have not been addressed. (score 12.10)
- 18.Spatially variable parameters have been measured for a very small percentage of the total volume of the geomedia existing in the INEEL subsurface. (score 12.07)
- 24.Geophysical logs and the tools for analyzing basalt logs are inadequate for conceptual model development. (New uncertainty) (score 11.69)
- 25.The extent of well construction affects on vadose zone and aquifer monitoring results is unknown. (New Uncertainty) (score 11.47)
- 21.Instrument bias and accuracy are often unknown. (score 10.97)
- 22.Quantifying the relative contributions to non-ideal behavior will require advances in detection and discriminatory analysis capabilities. (score 9.45)
- 8.Little is known about the effects of hydrothermal variations on flow and transport in the aquifer. (New uncertainty) (score 9.03)
- 3.Nonlinear governing equations for multiphase flow requires iterative solution schemes. (technical limitation) (score 7.29)

Meeting Process

The meeting was opened by Clay Nichols with welcoming remarks and an expression of the importance of the subject. Alan Yonk then presented a brief history of the Vadose Zone Roadmap and the uncertainties development. Copies of the slides used in that presentation can be found on page 54 of this record.

After the opening remarks the group held a discussion of the objective and process for the meeting. The risk following equation was presented as the foundation of the discussion:

Risk = Exposure Factor * Toxicity * Contaminant Concentration

It was explained that the first two factors of the calculation were determined by the regulatory agencies and were not within the control of this group. The third component of the equation is where this group does have some control and is where the uncertainties impact the overall risk.

As part of the objective discussion the group identified what IS/IS-NOT included in the objective. That discussion was recorded graphically in the following figure by drawing a boundary around what was included in the objective (inside the boundary) and what was not included in the objective (outside the boundary). The group originally identified the objective as prioritizing the vadose zone/groundwater uncertainties to reduce the doubt about the risk calculation, but later revised the objective to reduce the contaminant behavior. During the course of the meeting, the group referred to the IS/IS-NOT diagram several times.

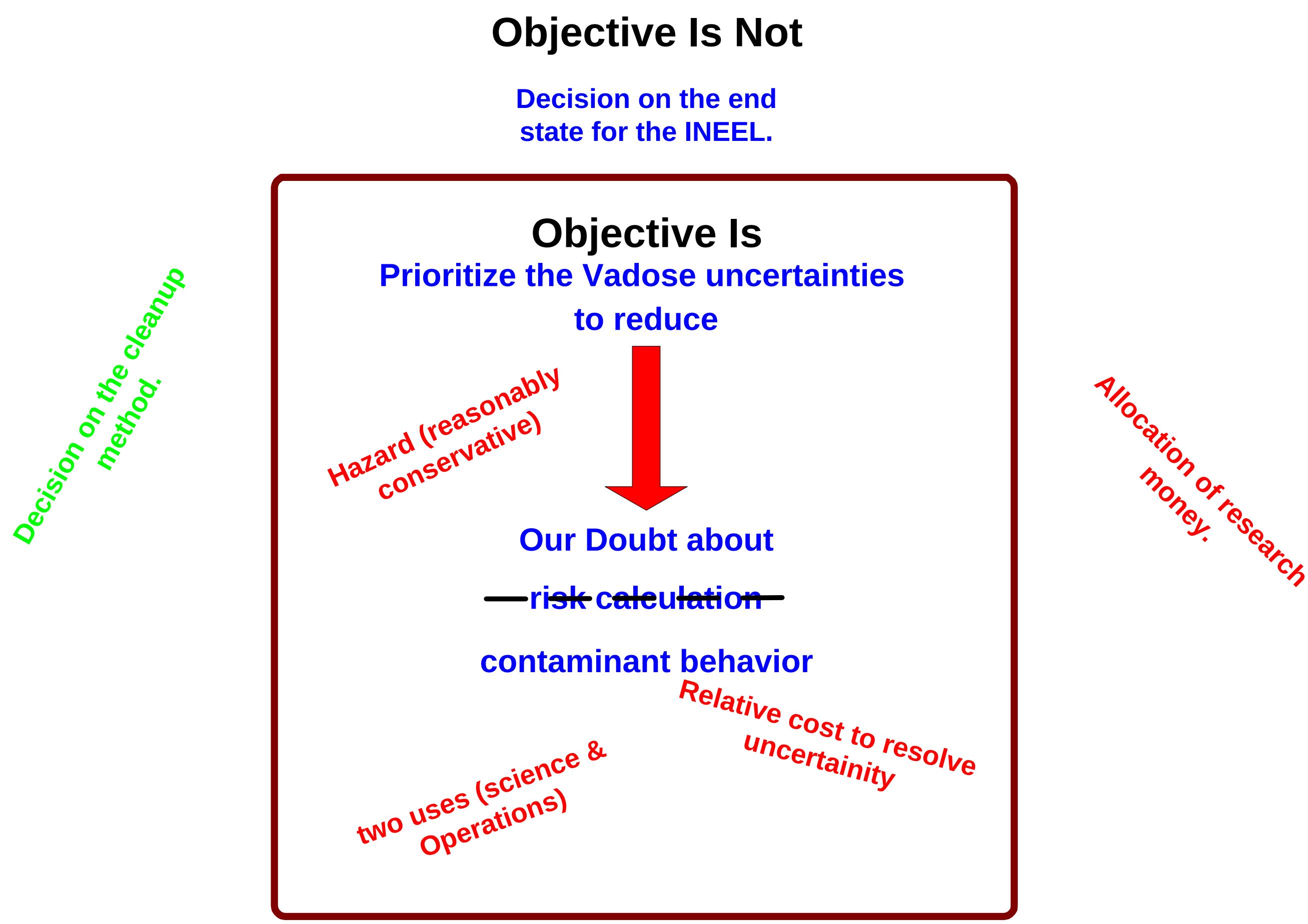

Figure 1. IS/IS-NOT description of the meeting objective.

After review of the objectives and process, the group discussed the list of vadose zone/groundwater uncertainties that had been identified by the Water Integration Project staff. Some of the uncertainties had been developed at a workshop in October of 1999. Those uncertainties were documented in *Uncertain Predictions of Contaminant Behavior at INEEL: A Roadmap for Addressing Current Limitations through Vadose Zone Studies.* The uncertainties identified in that report were refined, combined, and additional material added based on meetings between the Department of Energy (DOE), the Water Integration Project staff, and other knowledgeable scientists. The end result was a list of 25 uncertainties to be prioritized during this meeting. The list of uncertainties can be found on page 10 of this report.

The group agreed to work down through the list of uncertainties in multiple passes. The first pass would be to review the uncertainty for clarity and to make sure everyone understood the description. Subsequent passes through the list would be to merge, refine or delete uncertainties from the list. However, after making the first pass through the list for clarity, members of the group suggested that time would be better spent proceeding to criteria development and ranking the uncertainties. The group was not in consensus and was divided on the process change with DOE and INEEL participants in favor of the change and the stakeholder and other agency participants not in favor of the process change. With the majority of the group in favor of the change the group then broke for lunch.

Upon returning from lunch, the group was given time on the computers to comment on the uncertainties, ask questions and suggest changes to the uncertainties (see page 10 of this record for those comments). These comments would not be addressed during the meeting, but the Water Integration Project staff would review the comments and respond appropriately.

The group reviewed the elements of good criteria (see page 57 of this record). The participants were asked to individually list eight criteria that they personally believed would be good criteria for evaluating the uncertainties. After a few minutes of individual work, the members were asked to count-off from one to ten and then to get with others with the same number (there were nine groups of two people and one group of three people). Each pair were instructed to review each other's list of criteria and to jointly come up with a combined list of five criteria. The entire group then used a round-robin process to submit their list to the entire group. Pair one was asked to present their top criteria, then the next pair was asked to present their top criteria, or if already presented then present their next top criteria. This process was repeated until all the unique criteria had been captured from each pair. Seventeen criteria were identified from the round-robin process.

The group then discussed the criteria and merged some of the criteria into others because they were similar in meaning. The end result of the discussion was the identification of thirteen criteria for continued discussion. The group placed the thirteen criteria in rank order from the most important to the least important. The results of this rank order process can be found on page 23 of this report. After reviewing the rank sum scores, the group agreed to take the top seven criteria forward for further discussion. Discussion of the criteria regarded the degree to which a criterion met the guidelines for good criteria. The ability of a criteria to help discriminate between two uncertainties and the amount of overlap or "double-dipping" were significant components of the discussion. From this discussion, five criteria were identified that could be used to prioritize the uncertainties. The original criterion for "Long-term effectiveness and permanence" was set aside as not effective for discriminating between uncertainties.

Just prior to adjourning for the day, the group asked to rank order the five criteria from most important to lease important believing that this ranking would aid them in weighting the criteria the next morning. The results of this ranking process can be found on page 25 of this report.

On reconvening the next morning, the group was again asked if the five criteria currently under consideration met the guidelines for good criteria. This discussion resulted in the additional re-wording of two of the criteria. The criterion on "Maturity if the science" was set aside as not a good criterion. After the four criteria were finalized, the group was given time on the computers to comment on the criteria. The final four criteria can be found on page 5 of this report with supporting comments found on page 26.

During the discussion of the uncertainties the view was expressed, and supported by several participants, that some of the uncertainties were not actually uncertainties. Prior to weighting the criteria, the group was asked to answer the question "Is this an uncertainty?" The results of that question can be found on page 5 of this report with the detailed answers found on page 29. When asked if they could use the same criteria to prioritize those things they did not consider an uncertainty they indicated they could use the same criteria. However, the group wanted it clearly understood that while they could use the same criteria the things in question should not be considered an uncertainty and treated equally with the true uncertainties.

The group then did a pair-wise comparison of each of the criteria. This was done by comparing criteria one to criteria two and asking which was the more important criteria. Once the more important criteria was identified the group was asked to identify how much more important (on a scale of 1-9 with 1 being equal in importance and 9 being critically or absolutely more important). The identification of the important criteria was done verbally while the computers (using GroupSystems® opinion meter) were used to determine the degree of importance. The following table shows the results of the pair-wise comparison.

PAIRED COMPARISON MATRIX

Criteria		Return on investment.	Results are transferable to multiple programs, other sites and locations, and are crosscutting.	Is it practical to address the uncertainty.
Criteria		**2**	**3**	**4**
The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern.	**1**	1[3] 7	1 5	1 4
Return on investment.		**2**	2 4	4 4
Results are transferable to multiple programs, other sites and locations, and are crosscutting.			**3**	4 4

After the matrix was completed the results were transferred into the *Criterium DecisionPlus®* software package for calculation of the weights for each criteria. Those weights are found on page 5 of this report. *Criterium DecisionPlus®* software package calculated a consistency ratio of 0.167 and the software recommends a ratio below 0.10. The ratio of 0.167 indicates the group was slightly inconsistent in their rating of the criteria.

The group then discussed the scale to use when rating the uncertainties against the criteria. Given the limited information on the uncertainties, the group did not believe they could make any fine distinctions between the uncertainties and that a 1-10 scale would be too fine. They agreed that a 1-5 scale would be appropriate for rating the uncertainties. The group then proceeded to rate the uncertainties and when finished were free to go to lunch. The weighted priority of the uncertainties can be found on page 5 of this record with the detailed scoring matrix found on page 32.

Due to projection problems, the group was not able to review the graphical results (see page 46 of this report) of the prioritization. The individual uncertainty/criteria scores were reviewed by participants asking specific questions about the results. After reviewing the prioritization results, the group was given time on the computers to comment on the prioritized uncertainties. The prioritized order of the uncertainties, for commenting, was based on the criteria “The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern.” This prioritization for comments was used because the weighted results were not available, however, the results of this single criteria approximated the weighted results for all criteria. These comments can be found on page 49 of this report.

As a final activity, the group was asked to complete a meeting evaluation. The results of that evaluation are included in a separate report provided to the Water Integration Project leadership.

[3] The top or **BLUE** number indicates the criteria judged to be more important, the bottom or **GREEN** number indicates the degree of importance.

Review and discuss the uncertainties

1. Available field data are of insufficient quality and quantity for use in predictive simulation.

Translation: Much of the available field data are insufficient in most cases for model calibration because of insufficient frequency, density, quality and quantity. Available data are often sporadic or extremely low level detections that are uncertain. Because of these data problems, confidence in the data is low and they are determined to be unsuitable to use for model calibration, which is necessary before attempting predictive simulations.

In general the data are:

- Inconsistent - suggesting that transport occurs at one location and not at others with insufficient information limiting interpolation or extrapolation of processes or state variables.
- Insufficient - and do not provide consistent spatial or temporal trends that can be used in the model calibration process, or to discriminate between processes and parameters
- Inadequate - and do not provide the necessary parameter distributions to allow uncertainty to be quantified or bounded; uncertainty in hydrologic parameters (e.g., permeability and moisture characteristic curves) and in boundary conditions (e.g., infiltration history and spatial variability) limits the applicability of predictions for environmental-decision making.
- Incomplete - parameters including: matrix-fracture diffusion, microscale dispersivity, geochemical adsorption parameters, microbial activity (and indicators), unsaturated characteristic relationships for INEEL geomedia, have been obtained via literature review or guessed rather than measured. State variable and boundary condition distributions (water content, water potential, infiltration rates, evapotranspiration rates, temperature, and barometric pressure) are not recorded consistently, nor are the data interpretable when they are recorded. {#3[4]}

Disagree, predictive simulation is a simplification of the extreme heterogeneity that exists at INEEL. {#54}

The uncertainty is high level and forms the basis for the roadmap - how will this be broken down into a technology need/needs? {#55}

The purpose of these statements is that more data is needed to perform the analysis. {#56}

How do you know when there is enough data? {#57}

I doubt that there is any situation about which some prediction cannot be made. {#58}

Strongly agree, sample is strategy is largely determined by monitoring needs and not scientific criteria. {#61}

It should be noted that only a limited set of the more mobile contaminants of concern can be used for model calibration. Many of the contaminants of concern are not mobile enough to have been released and moved such that they could be detected and used for model calibration. Therefore, the data collection should be prioritized for mobile contaminants for modeling and as indicators during long term monitoring. {#62}

I assume that this item included both the lack of knowledge of the 3D heterogeneity in physical, chemical and biological parameters as well as the scarcity of data on contaminants and their possible migration. {#65}

The reliability of a given predictive simulation depends on and is limited by our understanding and predictability of future stresses on the system in question. {#67}

This is an assumption behind the current process. It is not an uncertainty written with sufficient detail or information that can be used to move forward in a meaningful fashion that can guide a program. {#69}

Not all data collection is conducted to support predictive modeling activities. The collection of data can also be used to support an enhanced understanding of natural processes that shed light on the

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[4] Numbers at the end of a comment were added by the computer sotware to tract comments as they are entered into the data base. These numbers were used by participants to reference, support, or oppose other comments.

conceptualization of the problem. If the data are insufficient, the data gaps should be specifically identified as a starting point for discussion. {#68}

The real issue is no calibration targets for the contaminant concentration in the vadose zone or aquifer. What is meant by calibration targets? {#70}

This uncertainty should be reworded to capture the idea that we're specifically uncertain about how frequency of data collection affects data quality. {#99}

I think the most profitable point to merge, edit the uncertainties is after we've established criteria. {#100}

The uncertainty is more in not knowing whether there is data of sufficient quantity and quality to support the needed level of prediction. {#105}

Uncertainty #1 should be reworded as follows. "It is uncertain how data as currently collected and used influences the reliability of model predictions." {#106}

The comment should clarify that selected field data are of insufficient quality (i.e.: episodic surface-water data) to permit any sort of predictive modeling exercise. Other data (stratigraphic framework data, for example), while needed refinement, can be used as is in a predictive model. {#108}

There is also an uncertainty that all collected data is accessible and usable. {#125}

An integrated database should be developed to capture all revel ant data. Also data should be "validated" and screened to maintain a high quality product. {#139}

The statement is too vague to be useful. You would need to apply a Data Quality Objective process to each and every source and potential source to assess the value of the available data. {#149}

These uncertainties must be tied to remediation/compliance drivers - if not, this is a wasted exercise. {#158}

I agree with #149 - the statement is too vague and is too universal to be of any value. {#160}

2. Conceptual Models are often inadequate for prediction because they do not incorporated necessary physical and biogeochemical processes.

Translation: Models are still highly simplistic and often fail to capture the complex interplay of physical, chemical and microbial processes in the subsurface. Such processes could be mobilizing, immobilizing or having no effect on contaminant movement. The simplicity of the models results from a sparsity of data to characterize the complex mechanisms and/or a lack of understanding of the mechanisms. For example, in the case of carbon tetrachloride at the RWMC, the impact of microbial degradation is unknown.

- Definitive mechanisms describing water movement through the unsaturated fractured basalts has not been identified for the wide range of moisture conditions experienced at the INEEL. Simulation paradigms are based on ideal processes and do not represent observed behavior. Equivalent porous media approaches are used without basis, neglecting fracture-matrix interactions. Preferential flow, (water bypassing the majority of the subsurface medium), probably occurs throughout the INEEL, and is not represented in existing models. There are no generally accepted mathematical representations of advective processes occurring in variably saturated fractured media.
- Mechanisms describing transformation and reaction processes incorporated into predictive models are overly simplistic. Facilitated transport mechanisms (including the formation of colloids) are not incorporated, and the underlying mechanisms have not been identified. Linear equilibrium adsorption assumptions have formed the basis of all predictive simulations without consideration of rate-limitations, solubility-limitations, effect of pH, redox state, temperature effects, or specific INEEL mineralogy. Vapor phase contaminant behavior has not been well represented, based in part on assumptions of single water-phase rather than two- (mobile water and air) and three-phase (oil, water and air) flow considerations. The latter would require developing site-specific constitutive parameters describing the relative permeability-saturation relationships for 2- and 3- phases. Modeling done in support of predicting TCE and CCl 4 transport have not been based on constitutive relationships for INEEL media.
- Biogeochemical mechanisms and parameters are not incorporated, and historical studies have neglected degradation and transformational processes.
- Evaluations of several sites have been made on "presumably overly conservative parameterizations" without adequate process and parameter knowledge to confirm the hypotheses. Data requirements and experimental protocol for testing process model hypotheses are undefined. {#5}

What conceptual model does this statement refer to - DOE, USGS, others? Who is not incorporating the necessary physical and biogeochemical processes? {#64}

Conceptual models should be designed to make reasonably conservative predictions where risk of error results in significant adverse impacts to health or the environment. Simple models allow for comparison against limited data rather than waiting and attempting to find patterns in a large universe of data. {#71}

What we finally want to know is whether and how fast contaminants are moving. The detailed mechanisms of how they are moving are secondary. {#72}

Conceptual models should not be considered predictive tools. They should be a set of hypotheses which can be tested with numerical models. {#109}

Items 2, 11, and 16 all address the topic of mechanisms that may be important to understanding waste migration and could be merged. {#111}

Conceptual models need to be just complicated enough to consider the processes that may substantially affect contaminant migration in the subsurface. {#122}

The practical constraints of collecting field data limit the application, without assumptions, of some of the simplest models. Reasonable assumptions must be made to predict outcomes for decision making. {#124}

Too often predictive models are considered the last word and be comprehensive. The models need to be designed to be flexible yet meet the immediate needs of programs. {#135}

The development of an accurate conceptual model is the very most important first step to developing predictive abilities. The conceptual model identifies the process involved and how they interact. I don't like the word "simplistic" because that misses the point of the conceptual model. The conceptual models are at too high a level in that they do not address the processes, more like the effects. {#147}

3. Nonlinear governing equations for multiphase flow requires iterative solution schemes. (technical limitation)

Translation: This is a technology limitation. The computer simulations for vadose zone flow and transport solve non-linear governing equations, which require iterative solution schemes. As a result computer simulation times are often in the range of hours to weeks. Thus simple conceptual models are chosen to cut down the computer simulation time. Resulting in simple representations of the subsurface heterogeneity and geochmical properties. As well as simplifying assumptions such as steady state flow to address transient events such as episodic recharge and deterministic assessments when probabilistic assessments are needed.

- Excessively long elapsed time for forward simulations
- Limited discretization and insufficient incorporation of spatially variable lithostratigraphy and associated hydrogeochemical transport properties
- Assumptions of steady-state flow conditions, neglecting analyses and incorporation of highly variable transient recharge events
- Limited use of probabilistic sensitivity and uncertainty analysis. Predictions of contaminant concentrations are based on single pass forward simulations without consideration of new data, and without incorporating a model-data feedback mechanism. {#7}

Well then, go ahead and use an iterative procedure. {#66}

We need to look at how the model will be applied to determine if the iterative approach is cost-effective. {#73}

This is a technology limitation with respect to addressing the conceptual model uncertainty captured in #2. I would leave this out of the uncertainty list. {#119}

This is more of a limitation than an uncertainty although simplification causes some uncertainty in predictions. This is more of a hardware/software issue but it too is limited by the availability of appropriate data for input to model variables. {#138}

This is not an uncertainty. It is a factor to consider in developing models and understanding a reason why simple ones may be good. {#141}

This is a technology limitation, not an uncertainty. {#150}

4. Various sources of uncertainty and their relative impact on the predictability of transport is unknown and currently unqualified.

Translation: No quantitative method has been developed to account problems with data quality and sparcity, as well as the simplicity of the model itself. Methods of dealing with uncertainty similar to those developed for seismic hazards assessment are needed in order to determine how much confidence we should have in the modeling results.

- Impacts of temporally and spatially variable parameters, boundary conditions, and initial conditions have not been addressed as they contribute to uncertainty
- Data quality and bias, as they contribute to uncertainty, have not been addressed
- Methodology for assessing uncertainty - as opposed to sensitivity - has not been formalized. {#9}

Should this item read "Various sources of uncertainty...is unknown and currently UNQUANTIFIED"? {#59}

If we use a probabilistic approach we still need to collect enough representative data to predict the distribution and its range of values for each variable. {#74}

Although this is quite loosely worded, it highlights the question of how much uncertainty is acceptable, which probably is dependent on more than a risk number. {#132}

The problem with a statistical approach for quantifying uncertainty is the necessity to collect enough data to define data distributions for at least the key variables. This can be very resource intensive. {#148}

5. Knowledge of stratigraphic and structural controls on flow patterns in the vadose zone and the aquifer is limited. (New uncertainty)

Translation: Available geologic data are insufficient and too sparse to determine geologic controls for most of the site area outside of the facility areas. {#11}

Assuming vadose zone flow is primarily 1D, we need to know flow of contaminants from sources and potential sources. Therefore, stratigraphic & structural controls need to be known only for the immediate area of sources. Also, we need to recognize the inherent uncertainty with this approach. For example knowing the probably stratigraphy & structure of a linned pool may be insufficient to find the crack in the liner which allows for contaminant release. {#75}

The lack of knowledge in this area is vital to the understanding of contaminant transport on the regional scale. {#120}

Knowledge in this area is also vital when siting new facilities or attracting other programs/projects to the Site. {#129}

The assumption of 1D flow in the unsaturated zone has been demonstrated to be unrealistic (work by Rightmire and Lewis at RWMC, large-scale infiltration test, and the spreading area tracer test). It definitely would add uncertainty to any derived solutions to solute transport problems. {#140}

A more thorough knowledge of the framework geology is needed to define the hydraulic properties and distributions that control contaminant transport in areas of concern, mainly in the potential or existing plume areas for the contaminant sources. {#159}

6. Limited information is available on possible vertical transport in the aquifer. (New uncertainty)

Translation: Geologic and monitoring well data are limited and are insufficient to determine the amount of vertical water movement in the aquifer. {#13}

Yes, it is limited but it may be sufficient for reasonably conservative risk modeling. {#76}

#76 is a good comment. {#82}

Number 6 and 7 should be combined due to similar technical flow constraints! {#107}

Re comment #76 - It could also severely limit our ability to determine the ultimate fate of contaminants and our ability to monitor their movement. {#128}

Understanding of the distribution of head vertically and distribution of contaminants vertically is a necessary component of the sub-regional and local conceptual models of flow and transport. {#134}

7. Flow direction and temporal behavior in the aquifer is limited. (New uncertainty)

Translation: Available field and monitoring well data are insufficient at the depth of the aquifer to determine local flow direction and temporal behavior. This is due to insufficient well density and insufficient well depth (most wells just sample the very top of the aquifer). {#15}

There will always be limits to our knowledge. But in spite of our limitation on discussing risk, at the back of our mind is whether the uncertainty really matters in terms of risk. {#60}

I think that regionally, flow information is of sufficient quality for risk management purposes. {#77}

The concept of scale should be incorporated in this uncertainty. At the sub-regional scale, flow direction and distribution of head may be adequate in most areas. At the facility scale, this may not be true. {#127}

8. Little is known about the effects of hydrothermal variations on flow and transport in the aquifer. (New uncertainty)

Translation: Temperature data suggest that input of geothermal heat and water into the aquifer from depth is variable across the INEEL area. The effects on aquifer flow (velocity and direction) and groundwater chemistry are largely unknown. {#17}

How is this important to risk management modeling? {#78}

This seems to be a subset of number 7 and is not an uncertainty on its own. {#115}

Several of the uncertainties really raise the issue of scale. are we looking facility by facility, site wide, aquifer wide? That does highlight the importance of making certain we know why we're doing this. {#123}

9. Mechanisms and parameters describing adsorption of contaminants onto INEEL materials have not been adequately developed or measured.

Translation: The values used in models to describe the amount of a given contaminant that can be expected to be absorbed by the subsurface material it is passing through over time are estimates.

- The ideal transformation paradigm assuming linear-equilibrium-reversible adsorption, has not been tested or validated for INEEL geomedia, relevant solution chemistry, and contaminants.
- Adsorption mechanisms and parameters have not been established for INEEL materials (i.e., Kds are assumed to be correct, and literature derived values are assigned)
- Correlation between substrate properties, solution chemistry, and measured K d values have not been determined
- Interphase mass transfer reaction rates have not been evaluated for INEEL contaminants and media. Volatilization rates and release mechanisms from contaminated sediments and buried waste at the INEEL have not been established. The propensity of contaminants to travel in liquid and vapor phases (organic and water) has not been evaluated. {#19}

Predicting fate and transport over the long run in heterogeneous landfills like at the SDA provides for a large number of combinations of variables affecting adsorption. Thus, simplistic models with reasonably conservative assumptions allows for protective risk management decision-making. {#79}

A phased approach initially using simplistic conservative models for the SDA has not resulted in decisions regarding dispositions of SDA waste. {#97}

This topic could be merged with item 17. They cover the same ground. {#101}

There are a few uncertainties that can be merged into one: the following effects on transport, x, y., and z, are uncertain. {#112}

USGS studies concerning the sorption of stable strontium demonstrated several factors that strongly affected this process. An adequate development or measurement of sorption mechanisms and parameters should include assessment to determine which are important and which are not. {#152}

10. Conditions leading to facilitated transport are unknown.

Translation: We are unable to identify the conditions that facilitate contaminant transport in the vadose zone. For example, ultra-small particles called colloids may adsorb contaminants and stay suspended in water, possibly contributing to contaminant migration. While chemical components can absorb onto immobile solid particles of the rock matrix, they also can absorb onto these small colloidal particles that can be carried along with the flowing liquid phase. We don't completely understand the likelihood of contaminants to take the form of more than one phase or to form colloids. The phase of the contaminant directly affects its potential to migrate through the subsurface.

- Facilitated transport of actinides has not been evaluated although migration of Am-247 and Pu has apparently occurred at rates much faster than could be predicted by solute transport processes; it is unclear whether or not colloids exist in the SRPA waters and the conditions of formation are unknown
- Geochemical conditions required for development of colloids have not been demonstrated
- Combinations of K d values have not been shown to be able to represent facilitated transport within K d based simulators. Event driven transport (i.e., with a short duration and large water flux) of dissolved-phase contaminants could account for the discrepancies. Computer codes currently in use at INEEL do not explicitly account for facilitated transport. {#21}

The more appropriate question is whether these conditions can be reasonably bounded. {#80}

Not just conditions, but also transport mechanisms. Facilitated transport has been suggested, but how could it be tested to demonstrate that it is a problem, and how can data be gathered to establish transport parameters. {#131}

11. Microbial effects on contaminant degradation transport rates, and mechanisms in both the vadose zone and the aquifer have not been addressed.

Translation: Contaminants in the subsurface are affected by microbial populations. Accurate mathematical descriptions for these interactions do not exist. We do not completely understand the interactions between microbes and the various contaminants in the subsurface, as well as the rate and extent of biological changes. To date, we have collected insufficient data to allow meaningful conclusions to be drawn about microbial effects on contaminant transport rates in the vadose zone and the aquifer.

- Insufficient data are available to allow meaningful conclusions to be drawn about basic issues such as: which physiologies are present/active, how the organisms are distributed, and which physical and chemical factors control their distribution and activity.
- Study locations are inaccessible and remote, making detection of microbial activity difficult.
- Accessibility constraints force the requirement of costly sampling methods.
- Low levels of biomass in the vadose zone will require discrimination of low signals (i.e., autochthonous biomass) against a much larger background of potential contaminant organisms.
- Many organisms are unculturable, making estimation of in situ activity more difficult; assays must integrate molecular methods to evaluate microbial presence, potential, and activity. {#23}

Microbial effects are being evaluated at the OU 1-07b remediation. {#81}

Geochemistry is important in that geochemical processes can slow the movement of contaminants an order of magnitude or several orders of magnitude relative to the movement of water. Must link the fluid movement and geochemistry conceptual models. It does not serve to measure adsorption properties on interbeds if all of the water moves around interbeds along fast paths. {#136}

12. Near-field hydraulic conditions and their influence on contaminant release and migration are unknown.

Translation: The properties of the subsurface around a leaking containment vessel (such as a tank) will not reflect the properties of the surrounding area because this 'near-field' area was disturbed when the waste container was originally placed. The hydrology and vapor transport characteristics of this area will be different than the surrounding area. Water flow in this area is generally treated as a uniform process with the surrounding area although it is more likely that fluid flow is non-uniform and episodically event driven. In other words, there may be large flows as one large event and long periods of no flow through the near field materials. Field analytical methods are needed to be able to evaluate the effects of these types of flow conditions.

In general, the variability of water flow on the scale of individual waste containers is expected to be more significant because:

- Container and backfill materials are relatively non-uniform; soil porosity and permeability of the near-field environment differ from that of the general vadose zone environment because of the structural disturbance of the soil caused by excavation and backfilling, altering the hydrology and vapor transport characteristics of the near-field environment
- Modifications to the near-field hydrology by proposed remediation technologies (grouting, vitrification etc.) will only increase the contrasts.
- Current source term models treat water flow through the near-field environment as a spatially uniform process, although it is more likely to be non-uniform, event driven, and episodic. {#25}

To a layperson, the question of what's in the waste is very important. {#142}

13. Chemistry of the near-field environment (e.g. the oxidation-reduction potential and solubility effects) may significantly affect the release and the rate of migration. (Original 7 & 11 combined)

Translation: The chemistry of the near-field may significantly affect the rate of contaminant migration and this has not been factored into in situ waste treatment planning. For example, grouting mechanically stabilizes the waste but can also cause a significant alteration of the chemical environment for contaminant release. Solution chemistry refers to chemicals dissolved in liquid. Redox refers to oxidation-reduction potential of a chemical-which is a measure of chemical oxidation. Chemical oxidation helps to control how reactive (how likely to change and what it will react with) the chemical is in the subsurface environment.

- Oxidation-reduction potential and solubility effects are unknown, but may significantly affect the rate of migration to the general vadose zone
- Changes in the near-field chemistry resulting from in situ waste treatment options have not been evaluated. For example, grouting mechanically stabilizes waste but also can cause a nearly complete alteration of the chemical environment for release of contaminants.
- Redox states for contaminants and the effect on transport has not been evaluated. However, conditions are likely to vary between oxidizing in the native environment to reducing in the buried waste
- Organic complexing agents have not been evaluated in either soil or water, and anions are not always measured because they are not considered contaminants. The presence of complexing agents in waste and wastewater at the INEEL has not been evaluated, even though decontamination solutions containing complexing agents such as citrate, oxalate, and EDTA were used and disposed of by injection wells, released through spills, and buried in waste. These were co-disposed of with inorganic anions such as fluoride, carbonate, and phosphate that could be forming aqueous complexes with contaminants, but the propensity has not been evaluated.
- pH effects on the adsorption behavior of contaminants discharged in extremely low pH solutions has not been evaluated. {#27}

It is also true that the release may in turn affect the near-field chemistry, e.g., nitric acid release. {#83}

14. Temporal behavior of the containers and waste forms relative to contaminant release is unknown.

Translation: This uncertainty has two parts, 1) container failure and 2) release rates of contaminants to the environment, for transport in the subsurface. Of particular concern for container failure is the corrosion rates of metal containers. Of particular concern for releases to the environment are release rates due to corrosion of activated metals, leaching of contaminants from infiltrating water, and diffusion of volatile contaminates (organics, H-3, C-14) from failed or partially failed containers. We have little data on container failure processes and contaminant release from failed containers. Vapor release from failed containers occurs (in the vadose zone) but has not been quantified. Measurements we take today may not reflect what we see next year or ten years from now. We must understand the physical and chemical processes in order to understand the data.

- Release rates of volatile contaminants by diffusion and advection processes from partially failed containers are unknown. Contaminant release rates (particularly 3 H, 14 C, and volatile organic compounds) to the atmosphere are currently unmonitored.
- Kinetics and spatial characteristics of container failure processes are unknown
- Inventories of contaminants within the containers, and the fractions existing in mobile forms are unknown. {#29}

Container failure rate is important for mobile contaminants especially with short half life. However, for certain contaminants like C-14, the release is controlled by the corrosion of the base metal it is included in. So the corrosion rate controls the release. {#63}

I agree that predicting temporal effects for the long-term is of high uncertainty. {#84}

Contaminant release is related to container corrosion but is also related to other factors like solubility, redox, matrix effects, physical form of the contaminant, etc. {#143}

15. Contaminant Inventory Uncertainties (replaces original #14)

Translation: Simulating and estimating the effects of different contaminant sources is complicated by several factors. Estimates of contaminant inventories have significant uncertainties in both historical accidental release areas and disposals whose contents were not carefully recorded. Determining the extent of the contamination requires boring into the soil and burial sites, a potentially hazardous and expensive process that also brings contaminated materials to the surface. Release rates from a failed containment system are not measurable, and have to be estimated. Overall spill magnitude often has to be estimated as well. Existing invasive and non-invasive characterization methods have difficulty simulating and estimating the effects of different contaminant sources.

- Source delineation requires obtaining soil borings which: is potentially hazardous, brings contaminated materials to the surface, and is expensive.
- Techniques for in situ speciation of contaminants have not been developed, and non-intrusive methods to detect contaminant distributions are not available.
- Geophysical techniques for contaminant mapping are subject to interference presented by surface and subsurface structural features, and have not been tied to specific contaminants of interest. {#31}

I agree that obtaining representative physical samples and comparing the sample results against a conceptual site model reduces uncertainty. {#85}

This is a very important uncertainty for a CERCLA remedial action decision. Is it important to this process? Is source term part of the scope of this effort? {#110}

I would say the biggest of these inventory uncertainties is the present source term of chlorinated hydrocarbons in the buried waste. That is, how much hasn't yet leached out. {#144}

Knowledge of source term is very important to the uncertainty reduction. {#155}

Evaluating source term is a significant part of this effort - this leads directly to available contaminants. However, this work needs to be focused on the few nuclides and organics that actually impact risk. Np-237, I-129, c-14, etc. {#161}

16. The extent to which interactions between phases (vapor, liquid, organic interactions, etc.) affects transport is unknown. (New uncertainty)

Translation: Little data are available on how mixed phases (i.e. liquid and vapor) move through the vadoze zone or what reactions take place when different phases are mixed together. {#33}

There is some information from the OCVZ remedial action at OU 7-08. {#86}

There is a tremendous amount of constitutive theory and numerical implementation on this subject. It is clearly not resolved. I think this needs to be refined significantly to tie to INEEL issues. Otherwise, it is so broad that it does not provide guidance. {#121}

17. Temporally varying fluid saturations and pressures, precipitation, evapotranspiration, temperature, barometric pressure, etc., are collected sporadically.

Translation: As a result of a wide range of ongoing activities, properties such as soil pH, pressure, temperature, saturation, biological activity, oxidation, etc. are measured sporadically (both in terms of where, when and how often they are sampled), despite a direct interrelationship to weather changes, seasonal water flux, etc. Since short duration episodic events may affect infiltration and transport of contaminants, this results in data that has little or questionable value for predictive modeling purposes because there may be no data during the primary event. This complicates both remediation and modeling efforts. In other words, our monitoring campaigns have been of short duration, and have not coincided with important episodic events (such as flooding), so we know very little about the physical and chemical changes in the subsurface due to such events.

- Transient infiltration events are not captured through relatively short-term, discontinuous monitoring activities

- Insufficient record lengths do not span the range of infiltration conditions, and contribute to the long-term prediction uncertainty.
- Moisture content, pressure head, and contaminant concentrations are obtained at specific points in space and time. However, these state variables could very well be discontinuous in the heterogeneous environment, and values may not be representative of local vadose zone conditions. Secondary detection techniques are unavailable for confirmation of observed data.
- Correlation between measurements and indicators of hydrologic conditions (i.e., saturation and electrical resistivity) in the complex basalt-sediment materials have not been developed.
- Collecting and analyzing data is currently cost-, time-, and manpower intensive. {#35}

Agree! {#87}

How is this an R&D need? {#88}

This uncertainty could be combined with #1. {#104}

18. Spatially variable parameters have been measured for a very small percentage of the total volume of the geomedia existing in the INEEL subsurface.

Translation: Through a wide of range of activities, various parts of INEEL's subsurface have been only partially characterized. The subsurface is highly variable both on spatial and time scales. Large variability exists in structure, water saturation, hydrologic properties, composition, etc.

- Few ex situ laboratory estimates of unsaturated hydrologic properties (on small samples) and fewer in situ hydrologic property measurements have been made.
- Few analyses of sorptive properties, chemical composition, and mineralogic makeup of sediments, basalts, and fracture surfaces are available.
- Instruments and field tests allowing determination of unsaturated hydraulic characteristic in-situ are not available. Instruments and testing methods sample relatively close to boreholes, and the representativeness of the vadose zone environment is in question.
- Sorptive processes and parameters have not been established for the suite of geomedia found at the INEEL. Lacking representative mechanisms, Kds are assumed rather than obtained for specific conditions found at the individual disposal sites.
- Basalt characteristics (rubble zones, dense units, and fractured units) have not been mapped across the INEEL.
- Fracture characteristics (e.g., density, aperture, length, and orientation) have not been quantified.
- Volume averaged, or effective, properties are process and objective dependent
- Parameterizing simulation models using effective parameters (based on calibration) rather than process level values assumes that the system state is invariant
- Alterations in the system state (i.e., removal of anthropogenic water) requires alternate parameterizations.
- Spatial averaging of properties and processes may provide nonrepresentative integration of point measurements.
- Known lithostratigraphic variability requires an alternative to simply interpolating traditional borehole characterization data.
- Inverse models incorporating the relevant processes should be developed to assist in creating a consistent picture across all scales. {#37}

I agree, but the area studies is comparable with the area of know contamination. {#89}

Unfortunately, the area of known contamination will expand as we make D&D decisions for facilities with significant contamination in place. We need to have a good enough understanding of the subsurface that we can make these decisions based on good science rather than guesswork. {#153}

19. Relationships between extracted concentrations, small volume measurements of vadose zone parameters, biologic indicators, and state variables to those of the larger subsurface environment are unknown. (Combination of original #s 16,22, & 23)

Translation: It's difficult to determine how useful any subset of measurements are without comparing them to a comprehensive set of measurements. In a highly variable subsurface environment such as the INEEL's, variables such as fluid flow rates, soil pH, microbial populations, etc. can change dramatically from one location to another. The techniques to obtain these variables are not currently available. Using current technology, we are unable to comprehensively measure what is happening in the subsurface. We do not have a comprehensive data set for comparison.

- Colloids have been retrieved using suction lysimeters beneath the SDA, but it is not known if colloidal concentrations are represent the pore fluid in the vadose zone. Discrepancies can be introduced through the adsorptive and filtration properties of the lysimeters.
- Numerous organic contaminants have been detected in soil gas and groundwater samples, indicative of biodegradation processes. Direct in situ measurements of biologic activity are not available, as are correlations between soil gas and water samples to biologic activity. {#39}

Agree! {#90}

20. Preferred pathways are not detected or monitored, and there is relatively little information available.

Translation: INEEL's subsurface basalt layers have not been comprehensively characterized. Fracture characteristics such as orientation, length, density and aperture have not been quantified. Small scale preferred pathways are generally not important but preferred pathways on the facility scale need to be identified.

- Describing three-dimensional distribution of basalts and sediments and their hydrogeochemical characteristics.
- Delineating the interrelationship and interconnectivity of various fracture sets.
- Quantifying effective hydraulic characteristics of unsaturated fractured media.
- Describing surface topology and local ponding conditions. {#41}

There has been tracer studies performed in support of OU 3-13 & OU 1-07b remedial activities. {#91}

The existence of preferred pathways is a key uncertainty. It affects the rate of water movement through both the vadose zone and the aquifer, and also probably affects the retardation capability. {#102}

But I think it is known how long such preferred pathways are. That is, after what distances the irregularities even out. {#117}

The fact that pathways exist is a known fact off of the INEEL especially in the near surface basalts. The fact that they do exist offsite would indicate that they are present on site. {#126}

I think preferential flow pathways through the source term and the vadose zone are much more important than through the aquifer. {#151}

Tracer tests at TAN show that preferred pathways exist at INEEL. {#154}

21. Instrument bias and accuracy are often unknown.

Translation: The effects of installing instrumentation in the subsurface are still largely unquantifiable, and potential changes in instrument response with time are unknown. The accuracy of instrument readings is difficult to assess, and readings are often not comparable from one location to another.

- Current installation procedures are based on methodology developed for the agricultural and porous media applications. Installation procedures and their impact on measurements obtained in fractured media are unknown.
- Potential bias of (and the specific parameters represented for) instruments installed at fracture-well bore intersections have not been evaluated. Relative placement of instruments in dense basalt and fracture intersections can be determined via downhole video logs, but it is unclear whether water potential is reflective of that existing in the fractures or of that existing in the basalt matrix.
- Interaction and affect of porous media backfill with the fracture-matrix medium are unknown and the potential hysteretic effects involved are unquantified. {#43}

Agree! {#92}

Continued calibration of down-hole instrumentation can be problematic. {#114}

QA/QC procedures, audits and performance evaluation samples provide a measure precision and accuracy in sampling and analysis {#116}

Really? Completely unknown? {#118}

Instruments need to be developed for long term unattended monitoring. This would assist in the problem of not collecting data during episodic events. Accuracy will need to be assured in the long-term instruments. {#137}

22. Quantifying the relative contributions to non-ideal behavior will require advances in detection and discriminatory analysis capabilities.

Translation: Poorly understood physical and chemical processes at the pore or other small scales may have significant effects on the flow and transport at the field scale. This is a basic science uncertainty that needs to be addressed in order to improve our predictions of flow and transport. Because our understanding of the subsurface environment is incomplete, we base our investigations around an 'ideal' set of assumptions based on our current understanding. We cannot verify the assumptions because instruments and methodologies are not available to measure at small scales (such as flow in a fracture or fluid movement at a fracture-matrix interface).

For example:

- Current instruments and methodology cannot measure flow in single fractures or delineate fluid movement at fracture-matrix interfaces, verifying research hypotheses will require instrument development, advances in data analysis, and development of experimental protocol. {#45}

Only if such quantification provides value to reasonably conservative risk modeling, which I am unsure of its importance. {#93}

I'm not sure what this uncertainty is. {#162}

23. Laboratory-determined properties have not been related to field-scale values and conditions.

Translation: Laboratory scale experiments are generally not large enough to mimic the full complexity of geo/hydro/bio/chemical processes that occur in the real world subsurface. Because of this, data derived from laboratory research is instructive to some degree, but of limited practical application. We can't simply take laboratory observations, scale them up and then explain observations in the field-laboratory data is too simplistic and limited in scope.

- Methodology for translating laboratory-scale constitutive relationships to obtain field-scale properties for fractured media are not available.
- General scaling relationships have been developed for porous media that might be applicable to alluvial and sedimentary facies, but scaling relationships based on site-specific data have not been developed.
- Scaling relationships for fractured media have not been developed - and are probably objective dependent.
- Laboratory analyses of soil & rock cores collected in-situ yield a wide range of values. The use of ex situ assessment of properties and the associated measurement scale have not been evaluated.
- Appropriate scales of observation have not been defined, and are process dependent. For example, measuring the basalt-matrix permeability is of secondary importance if the fluid flow is primarily in the fractures of a larger system. Instrumentation and observation scale must be commensurate. {#47}

It is difficult to control variables in the field but lab studies have shown value, e.g., OU 1-07B In-Situ Bioremediation bench-scale studies. {#94}

Even the lab scale experiments that have shown to have application in the field may not have accounted for all the interactions, good and bad, that may occur in the field. {#157}

24. Geophysical logs and the tools for analyzing basalt logs are inadequate for conceptual model development. (New uncertainty)

Translation: Due to drilling methods and geophysical tools used at present and in the past on the INEEL, it is difficult to obtain physical and hydrologic parameters for the rocks and to correlate geophysical logs with the actual geology present. {#49}

I disagree if we are using a relatively simple conceptual site model. {#95}

This is not an uncertainty. This is a technology for gathering data to reduce uncertainty, but is not an uncertainty in and of itself. {#98}

I agree with #98 however, this is an area where we need to focus resources to ensure that we are capturing the right data. From the standpoint of where do I focus resources, it seems to me that we could spend a little bit of money and get a large benefit. {#113}

Agree with 98. {#130}

This uncertainty should really talk to the fact that geophysical methods for evaluating fractured rock are not as advanced as methods that are available for evaluating more homogeneous sedimentary materials. Fractured rock methods must be advanced to make the use of geophysical tools more applicable at the INEEL. {#145}

If they can't be used, then why are they being run on all the wells? {#156}

Near and proximal (10 to 1,000 ft) well-bore measurements. {#163}

A large body of geophysical log data is available for conceptualization. Rather, note that existing data do not permit quantification of hydrologic properties. {#164}

25. The extent of well construction affects on vadose zone and aquifer monitoring results is unknown. (New Uncertainty)

Translation: Data are insufficient to determine what changes in flow patterns and transport is caused by placing a monitoring well in the hydrostatic regime. Also, it is unknown what chemical changes are taking place near the monitoring well due to reactions of the groundwater with the well materials due to corrosion. {#51}

This may be correct in perched water areas. {#96}

These seem to be two different issues - well construction (design, construction materials, maintenance, etc.) and well placement. {#103}

Understanding of how the installation and use of a well affects the ability to monitor and contaminant transport would benefit the whole community as well as the INEEL. {#133}

Developing instrumentation to measure small-scale changes near a well is important. {#146}

Criteria identified for evaluating uncertainties

1. The uncertainty is large and has a significant impact on estimates of contaminate concentration.

2. Long-term effectiveness and permanence.

3. Technical complexity of potential solutions.

4. The range of the uncertainty corresponds to a significant variability of the risk.

5. Benefits to multiple to programs, how transferable to other sites and locations, crosscutting.

6. Is it an uncertainty?

7. Reduction in the LTS monitoring.

8. Has indirect benefits to the INEEL.

9. Low cost - high benefit.

Baseline relative cost to do the research to reduce the uncertainty. {#2}

Impacts to the lifecycle cost of decision. {#7}

10. Advances science.

11. Ability to completely resolve the uncertainty.

12. Maturity of understanding (short-term implementation vs long-term development).

Number of years for the task to bear fruit. {#8}

13. Level of controversy (regulatory community, scientific community, public).

Ability to alleviate public concerns. {#17}

Selection of criteria for additional development

Voting Results

Rank Order (Allow bypass)

Number of ballot items: 13

Total number of voters (N): 20

Rank Sum[5]

225	1. The uncertainty is large and has a significant impact on estimates of contaminate concentration.
206	2. Low cost - high benefit.
182	3. The range of the uncertainty corresponds to a significant variability of the risk.
181	4. Benefits to multiple to programs, how transferable to other sites and locations, crosscutting.
157	5. Long-term effectiveness and permanence.
153	6. Technical complexity of potential solutions.
145	7. Maturity of understanding (short-term implementation vs long-term development).
128	8. Advances science.
126	9. Has indirect benefits to the INEEL.
123	10. Level of controversy (regulatory community, scientific community, public).
87	11. Reduction in the LTS monitoring.
64	12. Is it an uncertainty?
43	13. Ability to completely resolve the uncertainty.

[5] Criteria above the red line were carried forward for additional development.

Number of Votes in Each Rating

The number in each cell of the matrix indicates the number of participants who placed the criteria at that position on the list.

	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean	STD	n
1. The uncertainty is large and has a significant impact on estimates of contaminate concentration.	10	3	1	3	1	0	0	1	0	0	1	0	0	2.75	2.69	20
2. Low cost - high benefit.	4	4	5	2	0	2	1	0	0	2	0	0	0	3.70	2.75	20
3. The range of the uncertainty corresponds to a significant variability of the risk.	3	4	4	0	1	1	1	2	1	1	2	0	0	4.90	3.52	20
4. Benefits to multiple to programs, how transferable to other sites and locations, crosscutting.	0	2	5	1	5	1	4	1	1	0	0	0	0	4.95	2.06	20
5. Long-term effectiveness and permanence.	0	1	1	4	3	4	2	2	1	0	1	0	1	6.15	2.68	20
6. Technical complexity of potential solutions.	1	1	0	2	3	5	2	1	2	2	1	0	0	6.35	2.62	20
7. Maturity of understanding (short-term implementation vs. long-term development).	0	2	1	4	1	3	1	1	2	1	2	2	0	6.75	3.31	20
8. Advances science.	0	2	0	1	2	1	4	1	2	4	2	1	0	7.60	2.93	20
9. Has indirect benefits to the INEEL.	0	0	2	1	1	2	1	6	2	2	2	1	0	7.70	2.58	20
10. Level of controversy (regulatory community, scientific community, public).	0	1	0	2	2	1	1	1	7	2	3	0	0	7.85	2.64	20
11. Reduction in the LTS monitoring.	0	0	0	0	1	0	3	2	2	4	4	3	1	9.65	2.11	20
12. Is it an uncertainty?	2	0	0	0	0	0	0	1	0	2	1	7	7	10.80	3.59	20
13. Ability to completely resolve the uncertainty.	0	0	1	0	0	0	0	1	0	0	1	6	11	11.85	2.39	20
Group consensus (1.00 = most consensus): 0.47																

Final criteria rank

Voting Results

Rank Order (Allow bypass)

Number of ballot items: 5

Total number of voters (N): 21

Rank Sum

98	1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern.
66	2. High benefit to cost.
64	3. Benefits to multiple to programs, how transferable to other sites and locations, crosscutting.
55	4. Is it simple enough to make progress.
32	5. Maturity of the science.

Number of Votes in Each Rating

	1	2	3	4	5	Mean	STD	n
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern.	16	3	2	0	0	1.33	0.66	21
2. High benefit to cost.	3	8	2	5	3	2.86	1.35	21
3. Benefits to multiple to programs, how transferable to other sites and locations, crosscutting.	1	4	12	3	1	2.95	0.86	21
4. Is it simple enough to make progress.	1	5	5	5	5	3.38	1.24	21
5. Maturity of the science.	0	1	0	8	12	4.48	0.75	21
Group consensus (1.00 = most consensus): 0.51								

Development and discussion of final criteria for evaluating uncertainties

1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern.

The uncertainty is large and has a significant impact on estimates of contaminate concentration. {#3}

The variability in the concentration of the contaminant(s) of concern is significantly sensitive to the uncertainty. {#29}

This means that a reduction in an uncertainty has an IMPACT on some program's decisions. {#30}

That is, the contaminant is of concern over at least a part of the concentration range corresponding to the range of the uncertainty in the parameter being considered. {#42}

This is the key objective to evaluate first. (From an operations but not a science point of view - jmm). {#49}

The word "significant" is somewhat subjective. Could the word "measurable" be used in its place? {#50}

The term "contaminant of concern" was included in this definition to convey the idea that work on uncertainties that address high risk contaminants is more important than work on uncertainties that do not address high risk contaminants. {#56}

This seems to me the most important criteria to meet the objectives of this meeting and the water integration program. More important, I this it is the most important to respond to some of Idahoans' concerns, particularly down-streamers who aren't in these meetings. What people want to know is where and in what concentration a contaminant will appear in the aquifer. {#61}

Figure of Merit should be calculated:

Probability of Tech success * Probability of implementation success * risk benefit {#68}

This is very dependent upon one's vision of what the goal is. Risk analysis is used in CERCLA remedial decisions and selected aspects of RCRA closure & corrective action. It may not be applicable to other regulatory programs. Also, different contaminants are pathway and risk scenario dependent as to whether they constitute a risk. Fate and transport modeling to predict a contaminant concentration may have parameters that may significantly affect the result, e.g., thickness of stratigraphic layers. {#69}

I agree with comment #50. {#70}

#61 is off base - what people want to know is the risk of a particular substance once it reaches the aquifer. {#77}

Agree with #48, this is an Operations driven program. {#78}

This is the critical criteria for ranking uncertainties; however, it assumes we already have a fundamental understanding about each uncertainty (i.e. whether or not it is "significant"). I'm not sure that is the case. {#83}

#83 makes a good point. {#84}

2. Return on investment

High benefit to cost. {#25}

Low cost - high benefit. {#13}

Baseline relative cost to do the research to reduce the uncertainty. {#2}

Impacts to the lifecycle cost of decision. {#7}

Simply means COST. {#31}

Mortgage reduction should be included as a benefit. {#35}

It means cost to implement. {#38}

Economic risk reduction will be considered. {#39}

The costs being considered are relative costs between uncertainties since none of us really knows what science research will be performed at this time. {#41}

With respect to this criterion, consideration should given to long term as well as short term implementation of research to address uncertainty reduction. {#44}

This uses life cycle cost analysis to determine whether implementing the project is more positive than the comparison project. {#47}

Secondary waste reduction should be part of this criteria. {#48}

Agree with #31. {#51}

ROI is a criteria for evaluating specific studies proposed to address an uncertainty, not the uncertainty itself. {#58}

We anticipate significant cost avoidance by reducing uncertainty. This may not always be the case. However, reducing uncertainty should allow less over design. The savings will come from avoiding costs of over design to account for uncertainty. {#60}

This is a valuable criterion after considering the first and last criteria (range of uncertainty and then practicality) as currently ranked. {#63}

This is not an important criteria at all. DOE, particularly headquarters, regards its own budget request to congress as an act of god. It is not. Solving the environmental problems at INEEL will be a time-consuming and costly venture. But our land, water, and children are worth it. {#66}

ROI means different things to different organizations. ROI can be acceptable for near, mid, or long term (0-3, 5-10, or 10 plus years). {#76}

This criterion should balance short term and long term objectives and their potential payback for investment. Therefore, the timing for payback should not be an issue. {#79}

3. Results are transferable to multiple programs, other sites and locations, and are crosscutting.

Benefits to multiple to programs, how transferable to other sites and locations, crosscutting. {#9}

The work should not just address near-term cleanup decisions, but should have an effect on the future of the INEEL. Can we better make siting decisions for new facilities (like research reactors). Can we understand long-term monitoring. {#37}

Is the uncertainty one that is viewed as applicable to other DOE sites and demonstrated research needs in general. {#40}

The DOE view cross cutting technologies between sites as a plus. Therefore, the transferability portion of this criteria is the important word. {#52}

Results include hiring staff and developing infrastructure that can be applied to other programs. {#62}

Results being in a methodology/approach to solving the problem. {#64}

Hiring staff (comment #62) is not part of this ranking criteria. {#67}

This is a useful balancing criterion to consider with the return on investment criterion. {#71}

This is where money can be saved legitimately. We're not saying we're not going to do it; we're saying we're going to do it efficiently. {#73}

4. Is it practical to address the uncertainty.

Is it simple enough to make progress. {#20}

Is it complex enough to be of value, but… {#21}

Technical complexity. {#5}

Practical is from the point of maturity of the science, historical success in the field, known processes to achieve the goal, etc. {#32}

Means IMPLEMENTABILITY. {#34}

Practicality is a criteria for evaluating specific studies proposed to address an uncertainty, not the uncertainty itself. {#45}

Some uncertainty will always be high. {#46}

What would be the performance measurement for this criteria???? Only the geoscience experts should vote on this one. {#53}

The uncertainty will always unknown. {#54}

Should not only view this in the current time frame but should also be visualized in a future sense. {#55}

This should probably be the second priority for evaluating uncertainties. If an uncertainty is not practical, there is little reason to evaluate further. {#57}

This is really an extreme case of the word "investment" in #2. {#59}

Implementability. Can we do it? Can we show measurable progress? {#65}

I agree with comment #65. This can be applied to both long and short-term projects. {#74}

This is a good criterion, but only if INEEL continues to revisit some of the uncertainty challenges that don't get funded because they fail to meet this criterion. Some challenges that are too complicated to tackle right now will, we hope, seem less insurmountable as other uncertainties are addressed. {#80}

Can the problem be well defined such that the uncertainty can be reduced in a "simple" straightforward manner {#81}

Other criteria considered, but not used, for prioritizing uncertainties

1. Long-term effectiveness and permanence.

Delete, this item is no longer relevant based on changes made to the other issues. {#33}

This item is no longer relevant, delete. {#36}

2. Maturity of the science.

Number of years for the task to bear fruit. {#8}

(Short-term implementation vs. long-term development). {#23}

This criterion is confusing and is covered by the other criteria. Delete. {#43}

Operations programs are primarily interested in science that is mature and can help NOW! {#72}

Maturity depends upon whether someone is talking about the theoretical basis, applied science experiences, or engineering applications. Bad example is gravity, the theoretical science is still immature but applied science and engineering is well established. {#75}

Immature science that is "high risk", that is without a known probability of success, needs to be included in the program otherwise this becomes an engineering exercise. The program needs to include some aspects that could have a significant impact in the long term, not just using research dollars to perform baseline ER or WM tasks. {#82}

Is it an uncertainty?

Voting Results

Yes/No (Allow bypass)

Number of ballot items: 25

Total number of voters (N): 20

Number of Votes in Each Rating

	Yes %	No %	n
1. Near-field hydraulic conditions and their influence on contaminant release and migration are unknown.	100.00	0.00	17
2. Mechanisms and parameters describing adsorption of contaminants onto INEEL materials have not been adequately developed or measured.	100.00	0.00	19
3. Knowledge of stratigraphic and structural controls on flow patterns in the vadose zone and the aquifer is limited. (New uncertainty)	100.00	0.00	20
4. Conditions leading to facilitated transport are unknown.	100.00	0.00	20
5. Chemistry of the near-field environment (e.g. the oxidation-reduction potential and solubility effects) may significantly affect the release and the rate of migration. (Original 7 & 11 combined)	100.00	0.00	20
6. Microbial effects on contaminant degradation transport rates, and mechanisms in both the vadose zone and the aquifer have not been addressed.	95.00	5.00	20
7. Temporal behavior of the containers and waste forms relative to contaminant release is unknown.	95.00	5.00	20
8. Various sources of uncertainty and their relative impact on the predictability of transport is unknown and currently unqualified.	94.74	5.26	19
9. Limited information is available on possible vertical transport in the aquifer.	94.74	5.26	19
10. Little is known about the effects of hydrothermal variations on flow and transport in the aquifer. (New uncertainty)	94.74	5.26	19
11. The extent to which interactions between phases (vapor, liquid, organic interactions, etc.) affects transport is unknown. (New uncertainty)	94.74	5.26	19
12. Relationships between extracted concentrations, small volume measurements of vadose zone parameters, biologic indicators, and state variables to those of the larger subsurface environment are unknown. (Combination of original #s 16,22, & 23)	94.74	5.26	19
13. Preferred pathways are not detected or monitored, and there is relatively little information available.	94.74	5.26	19
14. The extent of well construction affects on vadose zone and aquifer monitoring results is unknown. (New Uncertainty)	94.74	5.26	19
15. Flow direction and temporal behavior in the aquifer is limited. (New uncertainty)	90.00	10.00	20

	Yes %	No %	n
16. Contaminant Inventory Uncertainties (replaces original #14)	90.00	10.00	20
17. Laboratory-determined properties have not been related to field-scale values and conditions.	88.89	11.11	18
18. Spatially variable parameters have been measured for a very small percentage of the total volume of the geomedia existing in the INEEL subsurface.	85.00	15.00	20
19. Conceptual Models are often inadequate for prediction because they do not incorporated necessary physical and biogeochemical processes.	84.21	15.79	19
20. Instrument bias and accuracy are often unknown.	84.21	15.79	19
21. Quantifying the relative contributions to non-ideal behavior will require advances in detection and discriminatory analysis capabilities.	66.67	33.33	18
22. Temporally varying fluid saturations and pressures, precipitation, evapotranspiration, temperature, barometric pressure, etc., are collected sporadically.	61.11	38.89	18
23. Geophysical logs and the tools for analyzing basalt logs are inadequate for conceptual model development. (New uncertainty)	61.11	38.89	18
24. Available field data are of insufficient quality and quantity for use in predictive simulation.	55.00	45.00	20
25. Nonlinear governing equations for multiphase flow requires iterative solution schemes. (technical limitation)	30.00	70.00	20

Rating of the uncertainties against the criteria

Voting Results

A) Ballot

Method: Custom Method

Options: Allow Bypass

Descriptions: On a scale from 1 (low) to 5 (high)?

Vote On: Top Level Items of Both Lists

Uncertainty:

Top Level Items = 25

Criteria:

Items = 4

N: 22

B) Results Matrix

This table shows the average scores for each of the criteria within an uncertainty. The color of the cell indicates the level of consensus of the scores within that cell. A green cell indicates a higher level of consensus and a red cell indicates a lower level of consensus.

A consensus threshold value was set to help focus the group on those cells that had the most disagreement in the scores in the limited time available for discussion. It was not intended to imply that the group was in agreement on the score in that cell. The threshold level for consensus was set at 0.30. Typically, the threshold is set at 0.6 for discussion. The lower than normal threshold is indicative of the different perspectives of the participants.

Uncertainty / Criteria	1.	2.	3.	4.	Total	Mean	STD	Weighted Total
Weight[6]	2.36	0.44	0.24	0.96				
1.Available field data are of insufficient quality and quantity for use in predictive simulation.	4(3.86)	3(3.35)	3(2.52)	4(4.24)	13.97	3(3.49)	0.74	15.25
2.Conceptual Models are often inadequate for prediction because they do not incorporated necessary physical and biogeochemical processes.	4(3.86)	4(3.55)	4(3.57)	4(3.50)	14.48	4(3.62)	0.16	14.88
3.Nonlinear governing equations for multiphase flow requires iterative solution schemes. (technical limitation)	2(1.62)	2(1.75)	2(2.43)	2(2.20)	8.00	2(2.00)	0.38	7.29
4.Various sources of uncertainty and their relative impact on the predictability of transport is unknown and currently unqualified.	4(3.52)	3(3.20)	4(3.62)	3(3.45)	13.79	3(3.45)	0.18	13.90
5.Knowledge of stratigraphic and structural controls on flow patterns in the vadose zone and the aquifer is limited. (New uncertainty)	4(4.05)	4(3.75)	3(3.19)	4(3.67)	14.65	4(3.66)	0.36	15.49
6.Limited information is available on possible vertical transport in the aquifer.	3(3.48)	3(3.05)	3(2.86)	3(3.48)	12.86	3(3.21)	0.31	13.57
7.Flow direction and temporal behavior in the aquifer is limited. (New uncertainty)	4(3.67)	3(3.38)	3(2.67)	4(3.80)	13.51	3(3.38)	0.51	14.43
8.Little is known about the effects of hydrothermal variations on flow and transport in the aquifer. (New uncertainty)	2(2.19)	2(2.24)	2(2.38)	2(2.40)	9.21	2(2.30)	0.10	9.03
9.Mechanisms and parameters describing adsorption of contaminants onto INEEL materials have not been adequately developed or measured.	4(4.10)	4(3.95)	4(3.67)	4(3.71)	15.43	4(3.86)	0.20	15.85
10.Conditions leading to facilitated transport are unknown.	3(3.48)	4(3.67)	4(4.14)	4(3.52)	14.81	4(3.70)	0.30	14.19
11.Microbial effects on contaminant degradation transport rates, and mechanisms in both the vadose zone and the aquifer have not been addressed.	3(2.90)	3(3.05)	4(3.71)	3(3.14)	12.81	3(3.20)	0.36	12.10
12.Near-field hydraulic conditions and their influence on contaminant release and migration are unknown.	3(3.19)	3(3.33)	3(2.95)	3(3.14)	12.62	3(3.15)	0.16	12.72
13.Chemistry of the near-field environment (e.g. the oxidation-reduction potential and solubility effects) may significantly affect the release and the rate of migration. (Original 7 & 11 combined)	4(3.81)	4(3.71)	3(3.38)	3(3.48)	14.38	4(3.60)	0.20	14.77

[6] The weights used in this table were calculated from the weights developed earlier in the meeting. The criteria weights determined earlier were multiplied by the number of criteria. This transformation was done in order to put the unweighted total value and the weighted total values on the same scale.

Session: **Vadose Uncertainities 4/2 & 3/02**
Facilitated by: Buck West

Uncertainty / Criteria	1.	2.	3.	4.	Total	Mean	STD	Weighted Total
14.Temporal behavior of the containers and waste forms relative to contaminant release is unknown.	3(3.43)	4(3.52)	3(3.24)	3(3.19)	13.38	3(3.35)	0.16	13.48
15.Contaminant Inventory Uncertainties (replaces original #14)	4(3.81)	4(3.52)	2(2.48)	3(3.00)	12.81	3(3.20)	0.59	14.02
16.The extent to which interactions between phases (vapor, liquid, organic interactions, etc.) affects transport is unknown. (New uncertainty)	3(3.00)	3(2.95)	4(3.76)	3(3.05)	12.76	3(3.19)	0.38	12.21
17.Temporally varying fluid saturations and pressures, precipitation, evapotranspiration, temperature, barometric pressure, etc., are collected sporadically.	3(3.33)	3(3.45)	3(2.90)	4(3.81)	13.50	3(3.37)	0.37	13.74
18.Spatially variable parameters have been measured for a very small percentage of the total volume of the geomedia existing in the INEEL subsurface.	3(3.10)	3(2.80)	3(2.52)	3(3.05)	11.47	3(2.87)	0.26	12.07
19.Relationships between extracted concentrations, small volume measurements of vadose zone parameters, biologic indicators, and state variables to those of the larger subsurface environment are unknown. (Combination of original #s 16,22, & 23)	3(3.14)	3(3.05)	3(3.43)	3(2.90)	12.53	3(3.13)	0.22	12.37
20.Preferred pathways are not detected or monitored, and there is relatively little information available.	4(3.86)	3(3.20)	3(2.86)	3(3.05)	12.96	3(3.24)	0.43	14.12
21.Instrument bias and accuracy are often unknown.	2(2.33)	3(2.70)	4(3.71)	4(3.52)	12.27	3(3.07)	0.66	10.97
22.Quantifying the relative contributions to non-ideal behavior will require advances in detection and discriminatory analysis capabilities.	2(2.29)	2(2.30)	3(3.29)	2(2.35)	10.22	3(2.56)	0.49	9.45
23.Laboratory-determined properties have not been related to field-scale values and conditions.	3(3.33)	3(3.35)	3(3.43)	3(3.10)	13.21	3(3.30)	0.14	13.14
24.Geophysical logs and the tools for analyzing basalt logs are inadequate for conceptual model development. (New uncertainty)	3(2.67)	3(2.95)	3(2.86)	4(3.55)	12.02	3(3.01)	0.38	11.69
25.The extent of well construction affects on vadose zone and aquifer monitoring results is unknown. (New Uncertainty)	3(2.71)	3(2.75)	3(3.05)	3(3.25)	11.76	3(2.94)	0.25	11.47
Mean	3(3.23)	3(3.14)	3(3.14)	3(3.26)				
STD	0.64	0.52	0.49	0.47				

C) Vote Spread (Uncertainty)

This table shows the distribution of scores (1-5) across the four criteria for each of the uncertanities. The number within a criteria/score cell indicates the number of participants that used that score for that criteria. Within an uncertanity, the criteria are sorted from the highest to the lowest score. Footnotes reference explanations provided by participants regarding why they scored a criteria/uncertainity combination.

Criteria	1	2	3	4	5	Total	Mean	STD	n	Weighted Total
1.Available field data are of insufficient quality and quantity for use in predictive simulation.										
4. Is it practical to address the uncertainty. (0.96)	1	2	2	2	14[7]	89	4(4.24)	1.26	21	4.07
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	3		2	8	8[8]	81	4(3.86)	1.35	21	9.10
2. Return on investment (0.44)	4	2	2	7	5	67	3(3.35)	1.50	20	1.47
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	6	5	4	5	1	53	3(2.52)	1.29	21	0.61
2.Conceptual Models are often inadequate for prediction because they do not incorporated necessary physical and biogeochemical processes.										
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	2	3	2	3	11[9]	81	4(3.86)	1.46	21	9.10
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	1	4	4	6	6	75	4(3.57)	1.25	21	0.86
2. Return on investment (0.44)	1	4	5	3	7	71	4(3.55)	1.32	20	1.56
4. Is it practical to address the uncertainty. (0.96)	2	1	8	3	6	70	4(3.50)	1.28	20	3.36
3.Nonlinear governing equations for multiphase flow requires iterative solution schemes. (technical limitation)										
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	7	5	4	3	2	51	2(2.43)	1.36	21	0.58
4. Is it practical to address the uncertainty. (0.96)	8	4	5	2	1	44	2(2.20)	1.24	20	2.11
2. Return on investment (0.44)	9	7	4			35	2(1.75)	0.79	20	0.77
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	13	4	3	1		34	2(1.62)	0.92	21	3.82
4.Various sources of uncertainty and their relative impact on the predictability of transport is unknown and currently unqualified.										
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)		5	5	4	7	76	4(3.62)	1.20	21	0.87

[7] Gathering more data from existing instruments already in place is extremely practicle to do. At the INEEL we have tons of instrumentation in place,

[8] Data to calibrate predictive models would be a very effective way of decreasing uncertainty and gaining lots of credibility with stake holders. This would have very significant impact, both quantitatively and qualitatively on decreasing uncertainty in predictions.

[9] Getting the correct conceptual models of the system (the important processes) is a very effective way to reduce uncertainty. With the wrong processes in the conceptual models, uncertainty cannot be reduced.

Session: **Vadose Uncertainities 4/2 & 3/02**
Facilitated by: Buck West

Criteria	1	2	3	4	5	Total	Mean	STD	n	Weighted Total
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	2	3	6	2	8[10]	74	4(3.52)	1.40	21	8.32
4. Is it practical to address the uncertainty. (0.96)	1	2	9	3	5	69	3(3.45)	1.15	20	3.31
2. Return on investment (0.44)	2	6	2	6	4	64	3(3.20)	1.36	20	1.41
5.Knowledge of stratigraphic and structural controls on flow patterns in the vadose zone and the aquifer is limited. (New uncertainty)										
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)		1	5	7	8	85	4(4.05)	0.92	21	9.55
2. Return on investment (0.44)	1	2	4	7	6	75	4(3.75)	1.16	20	1.65
4. Is it practical to address the uncertainty. (0.96)		1	9	7	4	77	4(3.67)	0.86	21	3.52
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	2	4	6	6	3	67	3(3.19)	1.21	21	0.77
6.Limited information is available on possible vertical transport in the aquifer.										
4. Is it practical to address the uncertainty. (0.96)	1	2	8	6	4	73	3(3.48)	1.08	21	3.34
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	3[11]	2	5	4	7	73	3(3.48)	1.44	21	8.20
2. Return on investment (0.44)	3	4	5	5	3	61	3(3.05)	1.32	20	1.34
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	3	6	6	3	3	60	3(2.86)	1.28	21	0.69
7.Flow direction and temporal behavior in the aquifer is limited. (New uncertainty)										
4. Is it practical to address the uncertainty. (0.96)		2	6	6	6	76	4(3.80)	1.01	20	3.65
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	1	2	5	8	5	77	4(3.67)	1.11	21	8.65
2. Return on investment (0.44)	1	4	7	4	5	71	3(3.38)	1.20	21	1.49
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	3	8	4	5	1	56	3(2.67)	1.15	21	0.64
8.Little is known about the effects of hydrothermal variations on flow and transport in the aquifer. (New uncertainty)										
4. Is it practical to address the uncertainty. (0.96)	4	8	4	4		48	2(2.40)	1.05	20	2.30
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	6	6	4	5		50	2(2.38)	1.16	21	0.57

[10] This gets high marks because it should go before this whole exercise. Until you know where the problem is, how can you tackle it. Also, I sort of see this to include ways to deal with uncertainty and to carry it through the process.

[11] This is very site specific and is a secondary effect on transport. It also is a subset of the more general "direction of flow" in the aquifer, and I don't see that this deserves to be separated out.

Criteria	1	2	3	4	5	Total	Mean	STD	n	Weighted Total
2. Return on investment (0.44)	4	9	7	1		47	2(2.24)	0.83	21	0.98
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	9[12]	3	6	2	1	46	2(2.19)	1.25	21	5.17
9.Mechanisms and parameters describing adsorption of contaminants onto INEEL materials have not been adequately developed or measured.										
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)		1	3	10	7	86	4(4.10)	0.83	21	9.66
2. Return on investment (0.44)		1	6	7	7	83	4(3.95)	0.92	21	1.74
4. Is it practical to address the uncertainty. (0.96)		4	3	9	5	78	4(3.71)	1.06	21	3.57
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	1	2	4	10	4	77	4(3.67)	1.06	21	0.88
10.Conditions leading to facilitated transport are unknown.										
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)			6	6	9	87	4(4.14)	0.85	21	0.99
2. Return on investment (0.44)		3	6	7	5	77	4(3.67)	1.02	21	1.61
4. Is it practical to address the uncertainty. (0.96)		5	2	12	2	74	4(3.52)	0.98	21	3.38
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	2	2	7	4	6[13]	73	3(3.48)	1.29	21	8.20
11.Microbial effects on contaminant degradation transport rates, and mechanisms in both the vadose zone and the aquifer have not been addressed.										
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)		4	3	9	5	78	4(3.71)	1.06	21	0.89
4. Is it practical to address the uncertainty. (0.96)	3	2	6	9	1	66	3(3.14)	1.15	21	3.02
2. Return on investment (0.44)	3	5	6	2	5	64	3(3.05)	1.40	21	1.34
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	2	8	4	4	3	61	3(2.90)	1.26	21	6.86
12.Near-field hydraulic conditions and their influence on contaminant release and migration are unknown.										
2. Return on investment (0.44)	2	3	5	8	3	70	3(3.33)	1.20	21	1.47
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	2	4	7	4	4	67	3(3.19)	1.25	21	7.53

[12] This is a very specific study that has relatively little to do with the overall transport in the aquifer. It would also be involved to investigate with little bang for the buck.

[13] This mechanism is not currently included in conceptual models of transport. Understanding whether this is important has the potential to significantly reduce the uncertainty. The sporadic possible "hits" of Pu and Am in the aquifer at the SDA indicate how important this is. The current conceptual model cannot even explain the observed migration of Pu to interbeds under the SDA. Therefore, this leave a large uncertainty in the predicted results of any modeling effort.

Criteria	1	2	3	4	5	Total	Mean	STD	n	Weighted Total
contaminant(s) of concern. (2.36)										
4. Is it practical to address the uncertainty. (0.96)	1	4	8	7	1	66	3(3.14)	0.96	21	3.02
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	3	4	7	5	2	62	3(2.95)	1.20	21	0.71
13.Chemistry of the near-field environment (e.g. the oxidation-reduction potential and solubility effects) may significantly affect the release and the rate of migration. (Original 7 & 11 combined)										
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)		2	7	5	7	80	4(3.81)	1.03	21	8.99
2. Return on investment (0.44)		1	6	12	2	78	4(3.71)	0.72	21	1.63
4. Is it practical to address the uncertainty. (0.96)	1	2	6	10	2	73	3(3.48)	0.98	21	3.34
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)		4	9	4	4	71	3(3.38)	1.02	21	0.81
14.Temporal behavior of the containers and waste forms relative to contaminant release is unknown.										
2. Return on investment (0.44)	1	5	3	6	6	74	4(3.52)	1.29	21	1.55
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	1	4	4	9	3	72	3(3.43)	1.12	21	8.09
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	1	5	4	10	1	68	3(3.24)	1.04	21	0.78
4. Is it practical to address the uncertainty. (0.96)	2	5	5	5	4	67	3(3.19)	1.29	21	3.06
15.Contaminant Inventory Uncertainties (replaces original #14)										
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	1[14]	1	7	4	8	80	4(3.81)	1.17	21	8.99
2. Return on investment (0.44)	2	4	4	3	8	74	4(3.52)	1.44	21	1.55
4. Is it practical to address the uncertainty. (0.96)	3	5	7	1	5	63	3(3.00)	1.38	21	2.88
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	10	2	3	1	5	52	2(2.48)	1.69	21	0.59
16.The extent to which interactions between phases (vapor, liquid, organic interactions, etc.) affects transport is unknown. (New uncertainty)										
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	2		6	6	7	79	4(3.76)	1.22	21	0.90
4. Is it practical to address the uncertainty. (0.96)	2	5	5	6	2	61	3(3.05)	1.19	20	2.93
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	4	3	5	7	2	63	3(3.00)	1.30	21	7.08
2. Return on investment (0.44)	2	7	3	6	2	59	3(2.95)	1.23	20	1.30

[14] These low scores for source inventory reflect my bias that this does not belong here at all.

Criteria	1	2	3	4	5	Total	Mean	STD	n	Weighted Total
17.Temporally varying fluid saturations and pressures, precipitation, evapotranspiration, temperature, barometric pressure, etc., are collected sporadically.										
4. Is it practical to address the uncertainty. (0.96)		5	3	4	9	80	4(3.81)	1.25	21	3.66
2. Return on investment (0.44)		5	6	4	5	69	3(3.45)	1.15	20	1.52
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	1	7	2	6	5	70	3(3.33)	1.32	21	7.87
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	4	5	5	3	4	61	3(2.90)	1.41	21	0.70
18.Spatially variable parameters have been measured for a very small percentage of the total volume of the geomedia existing in the INEEL subsurface.										
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	1	8	4	4	4	65	3(3.10)	1.26	21	7.30
4. Is it practical to address the uncertainty. (0.96)	2	9	2	2	6	64	3(3.05)	1.47	21	2.93
2. Return on investment (0.44)	3	4	9	2	2	56	3(2.80)	1.15	20	1.23
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	3	8	7	2	1	53	3(2.52)	1.03	21	0.61
19.Relationships between extracted concentrations, small volume measurements of vadose zone parameters, biologic indicators, and state variables to those of the larger subsurface environment are unknown. (Combination of original #s 16,22, & 23)										
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)		4	8	5	4	72	3(3.43)	1.03	21	0.82
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	2	6	2	9	2	66	3(3.14)	1.24	21	7.42
2. Return on investment (0.44)	2	3	10	2	3	61	3(3.05)	1.15	20	1.34
4. Is it practical to address the uncertainty. (0.96)	1	8	6	4	2	61	3(2.90)	1.09	21	2.79
20.Preferred pathways are not detected or monitored, and there is relatively little information available.										
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)		4	4	4	9[15]	81	4(3.86)	1.20	21	9.10
2. Return on investment (0.44)	2	5	4	5	4	64	3(3.20)	1.32	20	1.41
4. Is it practical to address the uncertainty. (0.96)	1	9	4	2	5	64	3(3.05)	1.32	21	2.93
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	3	5	6	6	1	60	3(2.86)	1.15	21	0.69

[15] Preferred pathways have been consistently raised by regulatory agencies as a source of uncertainty and the reason for using extremely conservative assumptions in risk assessment models. Therefore, better understanding this phenomenon has a large potential to reduce uncertainty. Showing that these pathways exist may not save money, and may even show that the problem is bigger than we thought, but is a problem that has to be addressed. It will be very hard to implement (ie not very practicle) and may cost a lot of money, but we have some installations in place, like the vadose zone research park, where this work could be done relatively cost effectively.

Session: **Vadose Uncertainities 4/2 & 3/02**
Facilitated by: Buck West

Criteria	1	2	3	4	5	Total	Mean	STD	n	Weighted Total
21.Instrument bias and accuracy are often unknown.										
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)		4	4	7	6	78	4(3.71)	1.10	21	0.89
4. Is it practical to address the uncertainty. (0.96)	1	3	7	4	6	74	4(3.52)	1.21	21	3.38
2. Return on investment (0.44)	5	6	4		5	54	3(2.70)	1.53	20	1.19
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	6	8	3	2	2	49	2(2.33)	1.28	21	5.51
22.Quantifying the relative contributions to non-ideal behavior will require advances in detection and discriminatory analysis capabilities.										
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	1	3	8	7	2	69	3(3.29)	1.01	21	0.79
4. Is it practical to address the uncertainty. (0.96)	6	6	4	3	1	47	2(2.35)	1.23	20	2.26
2. Return on investment (0.44)	5	7	6	1	1	46	2(2.30)	1.08	20	1.01
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	5[16]	7	7	2		48	2(2.29)	0.96	21	5.39
23.Laboratory-determined properties have not been related to field-scale values and conditions.										
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	1	6	3	5	6	72	3(3.43)	1.33	21	0.82
2. Return on investment (0.44)		5	5	8	2	67	3(3.35)	0.99	20	1.47
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)		6	5	7	3	70	3(3.33)	1.06	21	7.87
4. Is it practical to address the uncertainty. (0.96)		8	5	4	3	62	3(3.10)	1.12	20	2.98
24.Geophysical logs and the tools for analyzing basalt logs are inadequate for conceptual model development. (New uncertainty)										
4. Is it practical to address the uncertainty. (0.96)	1	2	5	9	3	71	4(3.55)	1.05	20	3.41
2. Return on investment (0.44)	4	5	4	2	5	59	3(2.95)	1.50	20	1.30
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	4	4	4	9		60	3(2.86)	1.20	21	0.69
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	7	3	4	4	3	56	3(2.67)	1.49	21	6.29
25.The extent of well construction affects on vadose zone and aquifer monitoring results is unknown. (New Uncertainty)										
4. Is it practical to address the uncertainty. (0.96)		6	6	5	3	65	3(3.25)	1.07	20	3.12
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)	2	5	6	6	2	64	3(3.05)	1.16	21	0.73
2. Return on investment (0.44)	4	3	9	2	2	55	3(2.75)	1.21	20	1.21

[16] The low votes here mainly reflect my lack of understanding of the importance of this.

Criteria	1	2	3	4	5	Total	Mean	STD	n	Weighted Total
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)	4	8	3	2	4	57	3(2.71)	1.42	21	6.41

D) Vote Spread (Criteria)

This table shows the distribution of scores (1-5) across the uncertainties for each of the four criteria.

The number in each cell of the matrix indicates the number of participants who placed the criteria at that position on the list.

	1	2	3	4	5	Total	Mean	STD	n
1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern. (2.36)									
Mechanisms and parameters describing adsorption of contaminants onto INEEL materials have not been adequately developed or measured.		1	3	10	7	86	4(4.10)	0.83	21
Knowledge of stratigraphic and structural controls on flow patterns in the vadose zone and the aquifer is limited. (New uncertainty)		1	5	7	8	85	4(4.05)	0.92	21
Preferred pathways are not detected or monitored, and there is relatively little information available.		4	4	4	9	81	4(3.86)	1.20	21
Available field data are of insufficient quality and quantity for use in predictive simulation.	3		2	8	8	81	4(3.86)	1.35	21
Conceptual Models are often inadequate for prediction because they do not incorporated necessary physical and biogeochemical processes.	2	3	2	3	11	81	4(3.86)	1.46	21
Chemistry of the near-field environment (e.g. the oxidation-reduction potential and solubility effects) may significantly affect the release and the rate of migration. (Original 7 & 11 combined)		2	7	5	7	80	4(3.81)	1.03	21
Contaminant Inventory Uncertainties (replaces original #14)	1	1	7	4	8	80	4(3.81)	1.17	21
Flow direction and temporal behavior in the aquifer is limited. (New uncertainty)	1	2	5	8	5	77	4(3.67)	1.11	21
Various sources of uncertainty and their relative impact on the predictability of transport is unknown and currently unqualified.	2	3	6	2	8	74	4(3.52)	1.40	21
Conditions leading to facilitated transport are unknown.	2	2	7	4	6	73	3(3.48)	1.29	21
Limited information is available on possible vertical transport in the aquifer.	3	2	5	4	7	73	3(3.48)	1.44	21
Temporal behavior of the containers and waste forms relative to contaminant release is unknown.	1	4	4	9	3	72	3(3.43)	1.12	21
Laboratory-determined properties have not been related to field-scale values and conditions.		6	5	7	3	70	3(3.33)	1.06	21
Temporally varying fluid saturations and pressures, precipitation, evapotranspiration, temperature, barometric pressure, etc., are collected sporadically.	1	7	2	6	5	70	3(3.33)	1.32	21
Near-field hydraulic conditions and their influence on contaminant release and migration are unknown.	2	4	7	4	4	67	3(3.19)	1.25	21
Relationships between extracted concentrations, small volume measurements of vadose zone parameters, biologic indicators, and state variables to those of the larger subsurface environment are unknown. (Combination of original #s 16,22, & 23)	2	6	2	9	2	66	3(3.14)	1.24	21
Spatially variable parameters have been measured for a very small percentage of the total volume of the geomedia existing in the INEEL subsurface.	1	8	4	4	4	65	3(3.10)	1.26	21
The extent to which interactions between phases (vapor, liquid, organic interactions, etc.) affects transport is unknown. (New uncertainty)	4	3	5	7	2	63	3(3.00)	1.30	21
Microbial effects on contaminant degradation transport rates, and mechanisms in both the vadose zone and the aquifer have not been addressed	2	8	4	4	3	61	3(2.90)	1.26	21

	1	2	3	4	5	Total	Mean	STD	n
not been addressed.									
The extent of well construction affects on vadose zone and aquifer monitoring results is unknown. (New Uncertainty)	4	8	3	2	4	57	3(2.71)	1.42	21
Geophysical logs and the tools for analyzing basalt logs are inadequate for conceptual model development. (New uncertainty)	7	3	4	4	3	56	3(2.67)	1.49	21
Instrument bias and accuracy are often unknown.	6	8	3	2	2	49	2(2.33)	1.28	21
Quantifying the relative contributions to non-ideal behavior will require advances in detection and discriminatory analysis capabilities.	5	7	7	2		48	2(2.29)	0.96	21
Little is known about the effects of hydrothermal variations on flow and transport in the aquifer. (New uncertainty)	9	3	6	2	1	46	2(2.19)	1.25	21
Nonlinear governing equations for multiphase flow requires iterative solution schemes. (technical limitation)	13	4	3	1		34	2(1.62)	0.92	21
2. Return on investment (0.44)									
Mechanisms and parameters describing adsorption of contaminants onto INEEL materials have not been adequately developed or measured.		1	6	7	7	83	4(3.95)	0.92	21
Knowledge of stratigraphic and structural controls on flow patterns in the vadose zone and the aquifer is limited. (New uncertainty)	1	2	4	7	6	75	4(3.75)	1.16	20
Chemistry of the near-field environment (e.g. the oxidation-reduction potential and solubility effects) may significantly affect the release and the rate of migration. (Original 7 & 11 combined)		1	6	12	2	78	4(3.71)	0.72	21
Conditions leading to facilitated transport are unknown.		3	6	7	5	77	4(3.67)	1.02	21
Conceptual Models are often inadequate for prediction because they do not incorporated necessary physical and biogeochemical processes.	1	4	5	3	7	71	4(3.55)	1.32	20
Temporal behavior of the containers and waste forms relative to contaminant release is unknown.	1	5	3	6	6	74	4(3.52)	1.29	21
Contaminant Inventory Uncertainties (replaces original #14)	2	4	4	3	8	74	4(3.52)	1.44	21
Temporally varying fluid saturations and pressures, precipitation, evapotranspiration, temperature, barometric pressure, etc., are collected sporadically.		5	6	4	5	69	3(3.45)	1.15	20
Flow direction and temporal behavior in the aquifer is limited. (New uncertainty)	1	4	7	4	5	71	3(3.38)	1.20	21
Laboratory-determined properties have not been related to field-scale values and conditions.		5	5	8	2	67	3(3.35)	0.99	20
Available field data are of insufficient quality and quantity for use in predictive simulation.	4	2	2	7	5	67	3(3.35)	1.50	20
Near-field hydraulic conditions and their influence on contaminant release and migration are unknown.	2	3	5	8	3	70	3(3.33)	1.20	21
Preferred pathways are not detected or monitored, and there is relatively little information available.	2	5	4	5	4	64	3(3.20)	1.32	20
Various sources of uncertainty and their relative impact on the predictability of transport is unknown and currently unqualified.	2	6	2	6	4	64	3(3.20)	1.36	20
Relationships between extracted concentrations, small volume measurements of vadose zone parameters, biologic indicators, and state variables to those of the larger subsurface environment are unknown. (Combination of original #s 16,22, & 23)	2	3	10	2	3	61	3(3.05)	1.15	20

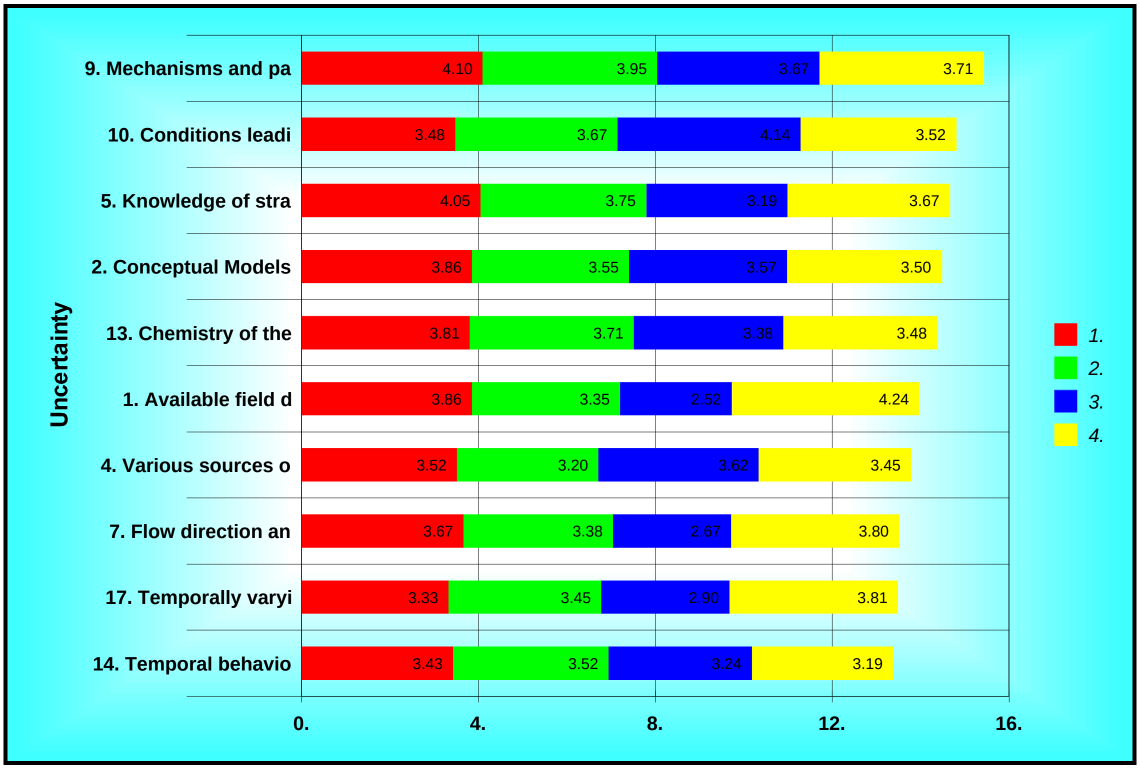
	1	2	3	4	5	Total	Mean	STD	n
Limited information is available on possible vertical transport in the aquifer.	3	4	5	5	3	61	3(3.05)	1.32	20
Microbial effects on contaminant degradation transport rates, and mechanisms in both the vadose zone and the aquifer have not been addressed.	3	5	6	2	5	64	3(3.05)	1.40	21
The extent to which interactions between phases (vapor, liquid, organic interactions, etc.) affects transport is unknown. (New uncertainty)	2	7	3	6	2	59	3(2.95)	1.23	20
Geophysical logs and the tools for analyzing basalt logs are inadequate for conceptual model development. (New uncertainty)	4	5	4	2	5	59	3(2.95)	1.50	20
Spatially variable parameters have been measured for a very small percentage of the total volume of the geomedia existing in the INEEL subsurface.	3	4	9	2	2	56	3(2.80)	1.15	20
The extent of well construction affects on vadose zone and aquifer monitoring results is unknown. (New Uncertainty)	4	3	9	2	2	55	3(2.75)	1.21	20
Instrument bias and accuracy are often unknown.	5	6	4		5	54	3(2.70)	1.53	20
Quantifying the relative contributions to non-ideal behavior will require advances in detection and discriminatory analysis capabilities.	5	7	6	1	1	46	2(2.30)	1.08	20
Little is known about the effects of hydrothermal variations on flow and transport in the aquifer. (New uncertainty)	4	9	7	1		47	2(2.24)	0.83	21
Nonlinear governing equations for multiphase flow requires iterative solution schemes. (technical limitation)	9	7	4			35	2(1.75)	0.79	20
3. Results are transferable to multiple programs, other sites and locations, and are crosscutting. (0.24)									
Conditions leading to facilitated transport are unknown.			6	6	9	87	4(4.14)	0.85	21
The extent to which interactions between phases (vapor, liquid, organic interactions, etc.) affects transport is unknown. (New uncertainty)	2		6	6	7	79	4(3.76)	1.22	21
Microbial effects on contaminant degradation transport rates, and mechanisms in both the vadose zone and the aquifer have not been addressed.		4	3	9	5	78	4(3.71)	1.06	21
Instrument bias and accuracy are often unknown.		4	4	7	6	78	4(3.71)	1.10	21
Mechanisms and parameters describing adsorption of contaminants onto INEEL materials have not been adequately developed or measured.	1	2	4	10	4	77	4(3.67)	1.06	21
Various sources of uncertainty and their relative impact on the predictability of transport is unknown and currently unqualified.		5	5	4	7	76	4(3.62)	1.20	21
Conceptual Models are often inadequate for prediction because they do not incorporated necessary physical and biogeochemical processes.	1	4	4	6	6	75	4(3.57)	1.25	21
Relationships between extracted concentrations, small volume measurements of vadose zone parameters, biologic indicators, and state variables to those of the larger subsurface environment are unknown. (Combination of original #s 16,22, & 23)		4	8	5	4	72	3(3.43)	1.03	21
Laboratory-determined properties have not been related to field-scale values and conditions.	1	6	3	5	6	72	3(3.43)	1.33	21
Chemistry of the near-field environment (e.g. the oxidation-reduction potential and solubility effects) may significantly affect the release and the rate of migration. (Original 7 & 11 combined)		4	9	4	4	71	3(3.38)	1.02	21

	1	2	3	4	5	Total	Mean	STD	n
Quantifying the relative contributions to non-ideal behavior will require advances in detection and discriminatory analysis capabilities.	1	3	8	7	2	69	3(3.29)	1.01	21
Temporal behavior of the containers and waste forms relative to contaminant release is unknown.	1	5	4	10	1	68	3(3.24)	1.04	21
Knowledge of stratigraphic and structural controls on flow patterns in the vadose zone and the aquifer is limited. (New uncertainty)	2	4	6	6	3	67	3(3.19)	1.21	21
The extent of well construction affects on vadose zone and aquifer monitoring results is unknown. (New Uncertainty)	2	5	6	6	2	64	3(3.05)	1.16	21
Near-field hydraulic conditions and their influence on contaminant release and migration are unknown.	3	4	7	5	2	62	3(2.95)	1.20	21
Temporally varying fluid saturations and pressures, precipitation, evapotranspiration, temperature, barometric pressure, etc., are collected sporadically.	4	5	5	3	4	61	3(2.90)	1.41	21
Preferred pathways are not detected or monitored, and there is relatively little information available.	3	5	6	6	1	60	3(2.86)	1.15	21
Geophysical logs and the tools for analyzing basalt logs are inadequate for conceptual model development. (New uncertainty)	4	4	4	9		60	3(2.86)	1.20	21
Limited information is available on possible vertical transport in the aquifer.	3	6	6	3	3	60	3(2.86)	1.28	21
Flow direction and temporal behavior in the aquifer is limited. (New uncertainty)	3	8	4	5	1	56	3(2.67)	1.15	21
Spatially variable parameters have been measured for a very small percentage of the total volume of the geomedia existing in the INEEL subsurface.	3	8	7	2	1	53	3(2.52)	1.03	21
Available field data are of insufficient quality and quantity for use in predictive simulation.	6	5	4	5	1	53	3(2.52)	1.29	21
Contaminant Inventory Uncertainties (replaces original #14)	10	2	3	1	5	52	2(2.48)	1.69	21
Nonlinear governing equations for multiphase flow requires iterative solution schemes. (technical limitation)	7	5	4	3	2	51	2(2.43)	1.36	21
Little is known about the effects of hydrothermal variations on flow and transport in the aquifer. (New uncertainty)	6	6	4	5		50	2(2.38)	1.16	21
4. Is it practical to address the uncertainty. (0.96)									
Available field data are of insufficient quality and quantity for use in predictive simulation.	1	2	2	2	14	89	4(4.24)	1.26	21
Temporally varying fluid saturations and pressures, precipitation, evapotranspiration, temperature, barometric pressure, etc., are collected sporadically.		5	3	4	9	80	4(3.81)	1.25	21
Flow direction and temporal behavior in the aquifer is limited. (New uncertainty)		2	6	6	6	76	4(3.80)	1.01	20
Mechanisms and parameters describing adsorption of contaminants onto INEEL materials have not been adequately developed or measured.		4	3	9	5	78	4(3.71)	1.06	21
Knowledge of stratigraphic and structural controls on flow patterns in the vadose zone and the aquifer is limited. (New uncertainty)		1	9	7	4	77	4(3.67)	0.86	21
Geophysical logs and the tools for analyzing basalt logs are inadequate for conceptual model development. (New uncertainty)	1	2	5	9	3	71	4(3.55)	1.05	20
Conditions leading to facilitated transport are unknown.		5	2	12	2	74	4(3.52)	0.98	21
Instrument bias and accuracy are often unknown.	1	3	7	4	6	74	4(3.52)	1.21	21

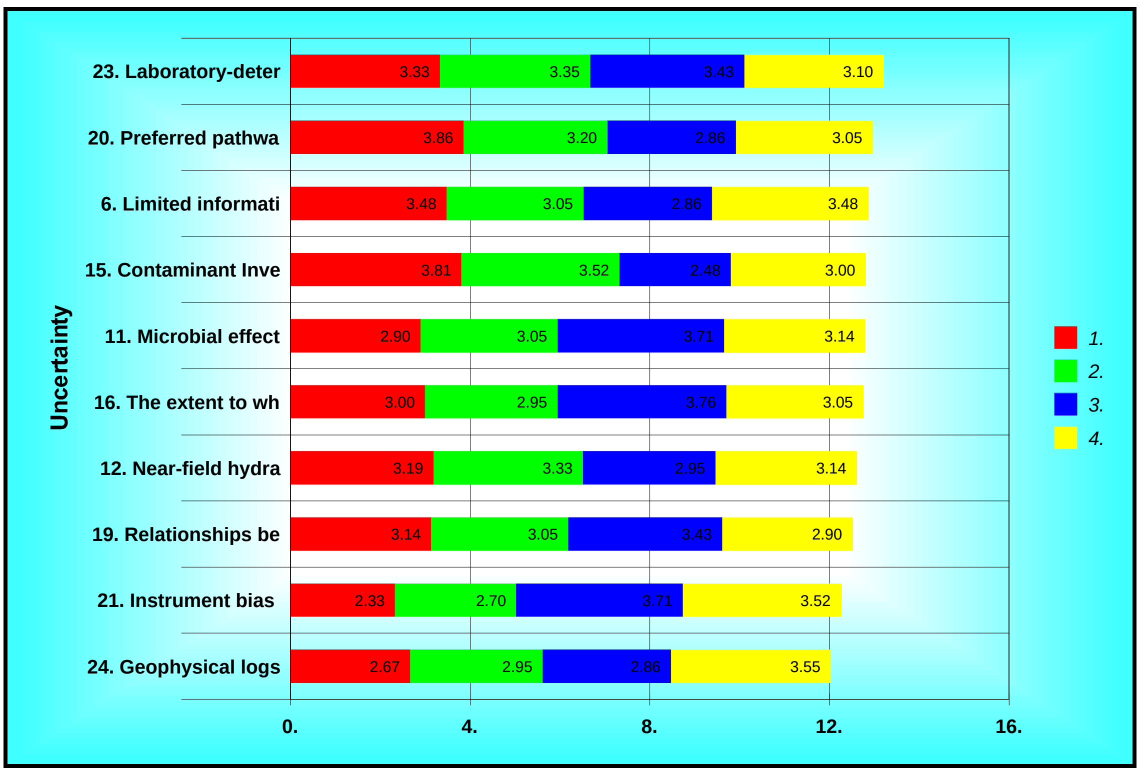
Session: **Vadose Uncertainities 4/2 & 3/02**
Facilitated by: Buck West

	1	2	3	4	5	Total	Mean	STD	n
Conceptual Models are often inadequate for prediction because they do not incorporated necessary physical and biogeochemical processes.	2	1	8	3	6	70	4(3.50)	1.28	20
Chemistry of the near-field environment (e.g. the oxidation-reduction potential and solubility effects) may significantly affect the release and the rate of migration. (Original 7 & 11 combined)	1	2	6	10	2	73	3(3.48)	0.98	21
Limited information is available on possible vertical transport in the aquifer.	1	2	8	6	4	73	3(3.48)	1.08	21
Various sources of uncertainty and their relative impact on the predictability of transport is unknown and currently unqualified.	1	2	9	3	5	69	3(3.45)	1.15	20
The extent of well construction affects on vadose zone and aquifer monitoring results is unknown. (New Uncertainty)		6	6	5	3	65	3(3.25)	1.07	20
Temporal behavior of the containers and waste forms relative to contaminant release is unknown.	2	5	5	5	4	67	3(3.19)	1.29	21
Near-field hydraulic conditions and their influence on contaminant release and migration are unknown.	1	4	8	7	1	66	3(3.14)	0.96	21
Microbial effects on contaminant degradation transport rates, and mechanisms in both the vadose zone and the aquifer have not been addressed.	3	2	6	9	1	66	3(3.14)	1.15	21
Laboratory-determined properties have not been related to field-scale values and conditions.		8	5	4	3	62	3(3.10)	1.12	20
The extent to which interactions between phases (vapor, liquid, organic interactions, etc.) affects transport is unknown. (New uncertainty)	2	5	5	6	2	61	3(3.05)	1.19	20
Preferred pathways are not detected or monitored, and there is relatively little information available.	1	9	4	2	5	64	3(3.05)	1.32	21
Spatially variable parameters have been measured for a very small percentage of the total volume of the geomedia existing in the INEEL subsurface.	2	9	2	2	6	64	3(3.05)	1.47	21
Contaminant Inventory Uncertainties (replaces original #14)	3	5	7	1	5	63	3(3.00)	1.38	21
Relationships between extracted concentrations, small volume measurements of vadose zone parameters, biologic indicators, and state variables to those of the larger subsurface environment are unknown. (Combination of original #s 16,22, & 23)	1	8	6	4	2	61	3(2.90)	1.09	21
Little is known about the effects of hydrothermal variations on flow and transport in the aquifer. (New uncertainty)	4	8	4	4		48	2(2.40)	1.05	20
Quantifying the relative contributions to non-ideal behavior will require advances in detection and discriminatory analysis capabilities.	6	6	4	3	1	47	2(2.35)	1.23	20
Nonlinear governing equations for multiphase flow requires iterative solution schemes. (technical limitation)	8	4	5	2	1	44	2(2.20)	1.24	20

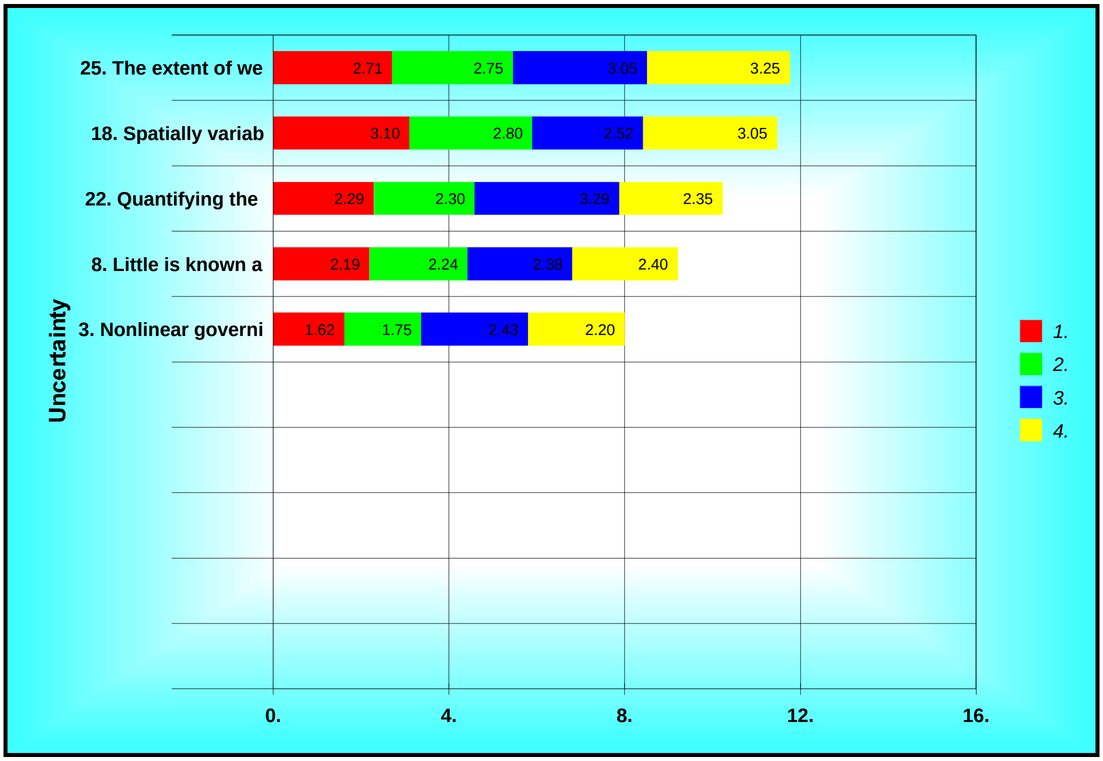
Result Charts



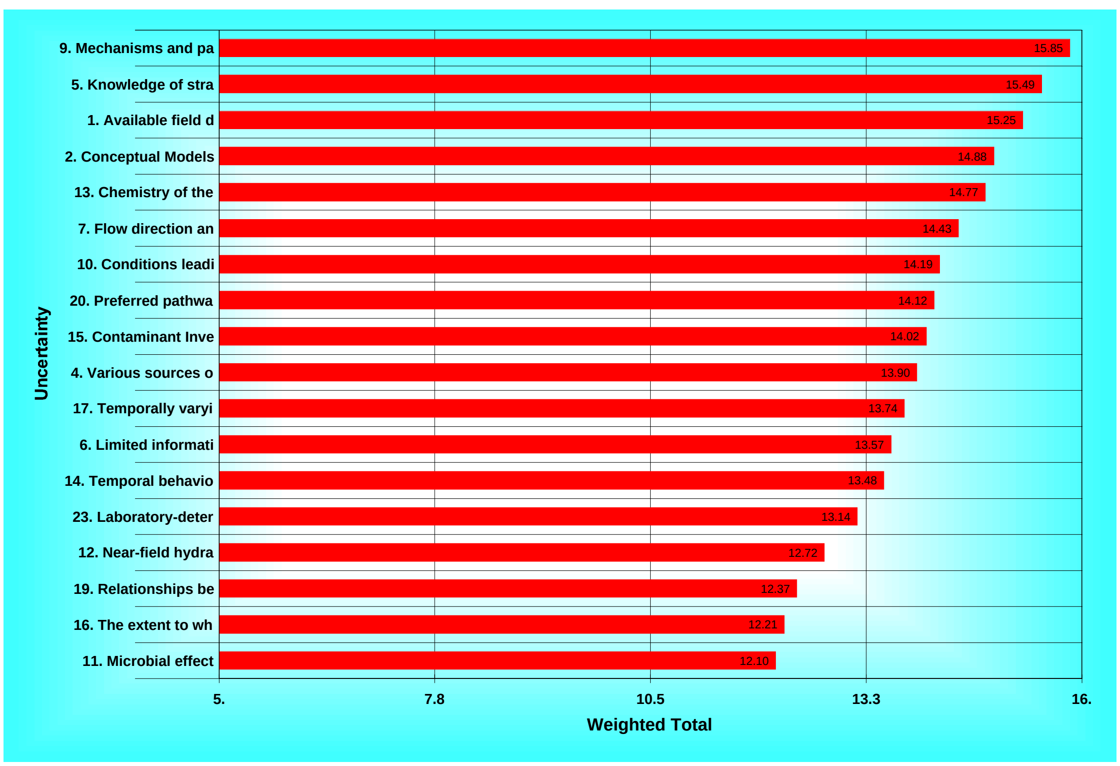
Unweighted criteria scores for each site (1 of 3)



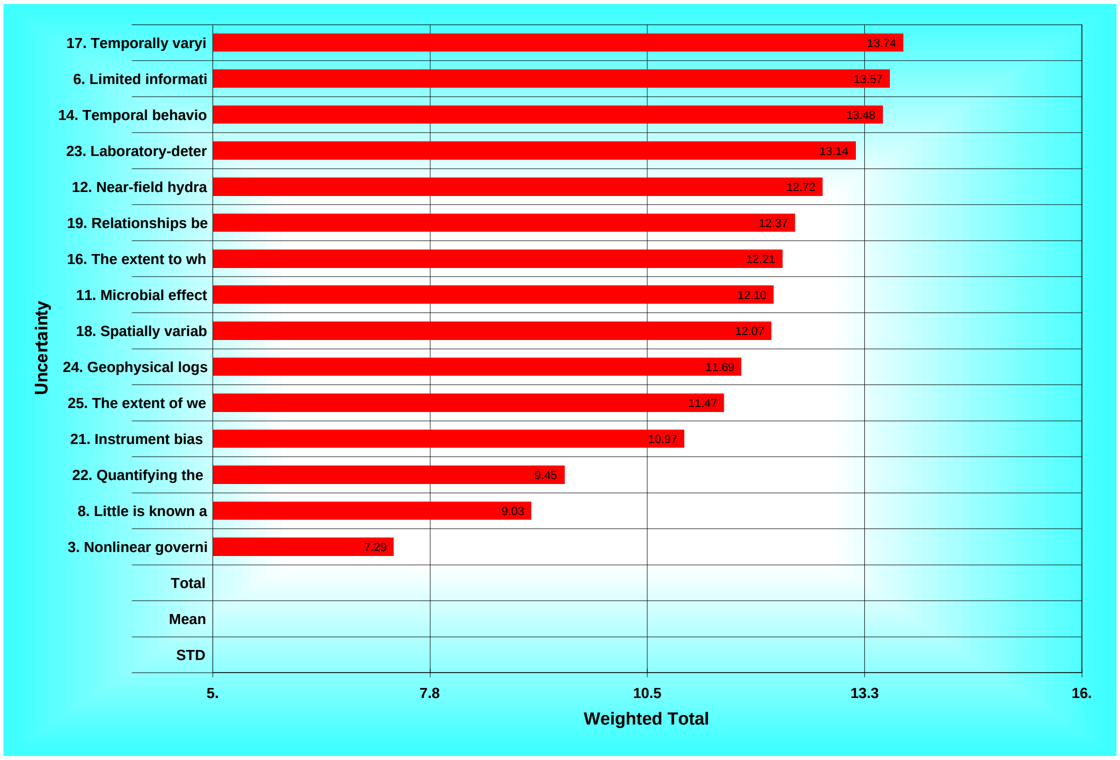
Unweighted criteria scores for each site (2 of 3)



Unweighted criteria scores for each site (3 of 3)



Uncertainties sorted by weighted total score (1 of 2)



Uncertainties sorted by weighted total score (2 of 2)

Participate comments on the uncertainty rank based on criteria #1

1. The range of the uncertainty corresponds to a significant variability in the concentration of the contaminant(s) of concern.

1. Mechanisms and parameters describing adsorption of contaminants onto INEEL materials have not been adequately developed or measured.

Variations in water residence time in the vadose zone range at most over an order of magnitude (20 years to 200 years). Geochemical retardation varies over several orders of magnitude. Therefore, the uncertainty in geochemistry has significant effect on radionuclides with half-life up to the hundreds of year range. {#105}

It's apparent that this ranking, weighting system will not obviate the need for a lot of coherent roadmapping work. Are there other uncertainties you will have to resolve before you can resolve this one? {#115}

Comment #115 points out the relationship of all of these uncertainties to each other. Has relationship been considered? {#127}

Overall very high weight for this criteria has probably skewed the data. {#148}

Generally, emphasis on adsorption processes has revolved around determinations of Kds. This is largely because of the ease of implementing this parameter in numeric models. Other techniques (such as the determination of selectivity coefficients) are also useful; however, use of these parameters has the advantage of accounting for competition between ions for adsorption sites. The disadvantage is that determination of these coefficients requires knowledge of the composition of the solid phase as well as the aqueous phase. Another disadvantage is that the numerical simulator would have to solve a series algebraic equations simultaneously. {#158}

We spent a lot of time thinking re applicability of this project to ER decisions. But another important application for resolved uncertainties will be better 5-year reviews under CERCLA. {#169}

2. Knowledge of stratigraphic and structural controls on flow patterns in the vadose zone and the aquifer is limited. (New uncertainty)

You can't do the conceptual models and have a good understanding of the flow unless you know the geology of the site. {#113}

This is particularly important if episodic events drive transport. {#121}

Stratigraphic and structural controls also impact flow and transport in the third dimension. {#125}

To reduce this uncertainty operations people who fund sample collection activities must be willing to pay for analysis for constituents that are needed by scientist to provide more accurate modeling parameters. Currently sampling and analysis is driven by regulatory needs. {#130}

Substantial effort (dollars and manpower) required to accomplish this control for the conceptual models. However, preferential flow regimes could be delineated. {#131}

This is one of those "no shit" statements. {#132}

If the operations people who fund sample collection are not approached/told/informed of other types of analyses and their benefit, then the opportunity to include other analyses won't be available. {#137}

3. Preferred pathways are not detected or monitored, and there is relatively little information available.

This has long been an issue with Wayne Pierre and has limited our ability to improve predictions of transport to the aquifer. It does not seem to be an issue in the aquifer on a small scale, but U and Sr isotope work indicates that there are large scale preferred flow paths at the INEEL. These will significantly affect travel times in both the vadose zone and the aquifer. {#134}

This is an extremely complicated uncertainty to deal with. Primarily because the magnitude of the problem is immense, and particular preferred pathway may not be long lived (or may be replaced by another. Because of the transient nature of the problem research should concentrate on quantifying the hydrogeologic (i.e. vertical fractures, sediment distribution, fracture density etc.) Factors that cause the preferred pathways to form. {#160}

4. Available field data are of insufficient quality and quantity for use in predictive simulation.

In additional to drilling wells, this could also be construed as development on inter-well observational techniques such as cross-borehole tomography is necessary. {#106}

While this may not have been considered a criteria in the discussions, when the question was asked as a go/no go if it was a criteria, 55% said it was not but 45% said it was. {#107}

By increasing the available field data on water potentials, water levels, movement of conservative and nonconservative natural chemicals, significant data on how the hydrogeologic system works can be obtained and used to calibrate predictive models. This will go a long way to decreasing uncertainty. {#108}

I think this should be reworded. The uncertainty is in how data, the lack of data, or the interpretation of the data, influences the reliability of the predictions. {#111}

The availability of existing data should also be included. The data may be high quality, but if it is stuck in someone's office in a box, then it has limited use. (Data availability and accessibility are being addressed through other pieces of the Water Integration Project. - JNP) {#116}

Agree with 111 - All predictions! {#119}

I agree with #116. {#123}

Also agree with #111, the quality of the data may be very good, just sparse. {#126}

The current database should have a QA/QC activity to eliminate spurious data. Next step should be an integrated system. {#140}

It seems some individuals have a tendency to place the blame on the field data, when in fact the problem may be the predictive simulation. Yesterday someone in this very room said "the data are not what I expect." GOOD! Remember the scientific method: collect observations to test hypotheses. {#167}

5. Conceptual Models are often inadequate for prediction because they do not incorporated necessary physical and biogeochemical processes.

In my opinion, conceptual models are inappropriate for predictive purposes. They should be a series of hypotheses to test and refine as knowledge of the system improves. {#112}

Agree with #112. Models should never be used as a basis for regulatory decisions. {#117}

Hanford found that one of the most important things that they did in their VZ/GW Integration project was to develop good conceptual models. {#129}

I agree with #112 in part, but what should be the basis of a regulatory decision if there isn't anything else to help in assist in the decision when impacts to the environment must be considered. {#143}

Many of the other uncertainties listed are merely a subset of "the conceptual model." Testing and updating the conceptual model should be the #1 goal of the research. {#146}

The conceptual model is the description of the important processes. It is hard to get it right if the important process are not included or are incorporated incorrectly. Therefore, the conceptual model has to be gotten right first. The conceptual model is not a "predictive" tool, but a "descriptive" tool. {#154}

6. Chemistry of the near-field environment (e.g. the oxidation-reduction potential and solubility effects) may significantly affect the release and the rate of migration. (Original 7 & 11 combined)

Geochemistry of the near-field environment (particularly like in pits and trenches), can change solubility and therefore radionuclide release rates by orders of magnitude. This translates into orders of magnitude changes in the timing of the concentration peaks. {#142}

7. Contaminant Inventory Uncertainties (replaces original #14)

There is still plenty of work needed to nail down inventories at the SDA and Tank Farm. {#110}

Agree with 110, there is also plenty of work needed as to what will be left after remediation. This is also part of the inventory. {#136}

This uncertainty should be viewed from the INEEL wide perspective and not any individual source area. Characterization has been limited in some cases by budget but more often by limitations on where drilling could occur to characterize the source terms. {#150}

8. Flow direction and temporal behavior in the aquifer is limited. (New uncertainty)

With respect to risk assessment, the aquifer behavior is not as important as the source release and vadose zone transport. I think this is more interesting than it is important to decision making. {#145}

I presume that temporal behavior refers to ground-water response to stresses (particularly large episodic stresses relating to recharge from surface-water sources). In that vein, local changes in gradient and flow paths can play a very important role in the transport of contaminants. In the last few years, our knowledge base has increased greatly regarding the role of spreading area and Big Lost River infiltration on flow and transport through the vadose zone and the aquifer. {#170}

I presume that this uncertainty is referring to the direction of groundwater flow, for instance do contaminant plume from one facility adversely impact another. At this time medium scale flow paths are not understood. {#178}

9. Various sources of uncertainty and their relative impact on the predictability of transport is unknown and currently unqualified.

It seems that quantifying uncertainty would be a benefit in communicating to the public and gaining their understanding and trust. It would have to be a method based on currently accepted means of quantifying uncertainty and/or accepted for use outside of DOE. {#149}

It would be of much greater benefit than suggested in comment #149. It would optimize data collection activities and provide decision-makers with modeling results whose uncertainty range is known, therefore allowing them to set risk limits and make more useful decisions. {#173}

10. Conditions leading to facilitated transport are unknown.

This seems like a logical break point at which to limit further consideration, work on the top 10. {#114}

This is a process that has not been considered in previous investigations of Pu and Am transport. Is necessary for a technically defensible prediction. {#124}

The first question to answer is: "Is it really happening?" {#141}

This uncertainty should be higher on the list. If contamination (radionuclides) are reaching the aquifer it is by this mechanism! {#168}

The break point to limit consideration should be at a logical point not at an arbitrary "Top 10" as specified in comment # 114. {#175}

11. Limited information is available on possible vertical transport in the aquifer.

Need to determine for dilution estimation. {#122}

This uncertainty also relates to uncertainty 2, uncertainty 4, uncertainty 8, and others in terms of the limited amount of water chemistry and other data in the third dimension. {#135}

12. Temporal behavior of the containers and waste forms relative to contaminant release is unknown.

The release of contaminants from corroding metals is a very big issue today, at the RWMC. Understanding corrosion is of primary concern and should somehow be captured. {#159}

13. Laboratory-determined properties have not been related to field-scale values and conditions.

A field-scale laboratory such as the vadose zone research park provides an excellent location to pursue this topic. Scaling of laboratory measurements to the field is a key issue in developing parameters for field scale simulation. {#118}

Agree with 118, the SGL would also be good if it happens. {#144}

There will still be some scale issues to deal with but the vadose zone research park should reduce the scaling required to go from the conventional lab scale approach to field application. {#165}

14. Temporally varying fluid saturations and pressures, precipitation, evapotranspiration, temperature, barometric pressure, etc., are collected sporadically.

This item (ranked #14) is partly so low because it overlaps with the #4 ranked item, and thereby dilutes the importance of data collection. I would combine the relative scores to determine overall significance. {#133}

I think this is not really an uncertainty but an approach to address the uncertainty captured in #4 on available field data. I suspect that the transport is episodically driven. If so, we can never capture this concept with sporadic data collection. {#138}

15. Near-field hydraulic conditions and their influence on contaminant release and migration are unknown.

The amount of water contacting and then migrating downwards past waste is a primary factor influencing resulting contaminant concentrations in the aquifer. I am surprised and disappointed that this rated so low. {#139}

Ditto to #139. {#147}

Heavily agree with #139. {#153}

It's interesting that near-field chemistry ranked fairly high but near-field hydraulics ranked low. I wonder if the participants incorporated concerns over how water affects release rates into their scores for the near-field chemistry uncertainty. {#164}

My thoughts were that any contaminant retardation in the near field would be insignificant in comparison to the far-field contaminant retardation. I wasn't thinking in terms of infiltration rates around the source term. {#171}

The source term drives risk. In addition, it is a topic that can be addresses in near surface field test, lab scale tests, and meso-scale tests. Reduction of the source term uncertainty has a higher likelihood of success than the vadose zone or aquifer uncertainties. I am surprised this rated so low. {#176}

16. Relationships between extracted concentrations, small volume measurements of vadose zone parameters, biologic indicators, and state variables to those of the larger subsurface environment are unknown. (Combination of original #s 16,22, & 23)

17. Spatially variable parameters have been measured for a very small percentage of the total volume of the geomedia existing in the INEEL subsurface.

18. The extent to which interactions between phases (vapor, liquid, organic interactions, etc.) affects transport is unknown. (New uncertainty)

19. Microbial effects on contaminant degradation transport rates, and mechanisms in both the vadose zone and the aquifer have not been addressed.

This uncertainty is came out fairly low, but the uncertainty of conceptual models not incorporating physical and biogeochemical process is high on the list. It will be difficult to address the latter uncertainty without working on this one. {#109}

Scientists spent years on the deep microbiology project on sites all over the US with little to show for it this may have influenced this low ranking. {#151}

Whether "little to show for it" as stated in comment #151 was that it was found the microbial effects had little consequence or that the techniques weren't available to find or understand the microbial processed would help determine if this should be pursued further. {#166}

20. The extent of well construction affects on vadose zone and aquifer monitoring results is unknown. (New Uncertainty)

Big area of concern to detect preferential pathways! {#177}

21. Geophysical logs and the tools for analyzing basalt logs are inadequate for conceptual model development. (New uncertainty)

If the INEEL could develop techniques to address this issue, they could be applied to other DOE sites as well as contaminated areas with similar geology. {#120}

While this uncertainty was rated low, it appears to me that a small investment in resources could yield a large impact in this area (high ROI). Need to consider funding for items like this where a small investment could give large results. {#152}

Comment #152 points out the fallacy of having one criteria rated so highly. {#156}

I am surprised that this is rated so low because, for new drilling, it is practical, relatively cheap, and could contribute significant new abilities to learn about physical, chemical, and hydrological property values and distributions. It requires developing or subcontracting to obtain state-of-the-art, calibrated, geophysical logs; and developing the appropriate mathematical relationships to calculate properties from the geophysical log data. We now have the in-house capability to do the second step (Russ Hertzog, who did much of that work for the petroleum industry and could do similar work for the shallow, water-saturated and vadose-zone basalt environment). It could go a long way towards addressing several of the other uncertainties (uncertainties # 1, 5, 6, 18, 19, 20, 21, 23, and 25, some of which are rated highly by Criterion #1). For most of the existing wells, which are cased with steel, it would not be so easy, but some of them have uncased sections of sufficient diameter to obtain really useful logging data. {#162}

If fracture permeability is one of the driving forces, then new geophysical logging measurements to detect fracture preferential pathways would not only be useful at the INEEL but also at other DOE sites like Oak Ridge. {#172}

This does not seem to me to be an uncertainty. It is a technology development project. It would be a good scientific investigation to refine stratigraphy. Since stratigraphy came out so high, this would be something to do to improve our understanding of uncertainty. {#174}

22. Instrument bias and accuracy are often unknown.

Better instruments with long life expectancies are needed for geoscience monitoring. {#157}

This is another area where some small investment in resources could potentially have a large impact on our understanding of the data that we gather. If our data is bad, it doesn't matter how much we have. {#161}

I agree with #161 and once again, it points out the problems with having such a high weight associated with criteria #1. {#163}

23. Quantifying the relative contributions to non-ideal behavior will require advances in detection and discriminatory analysis capabilities.

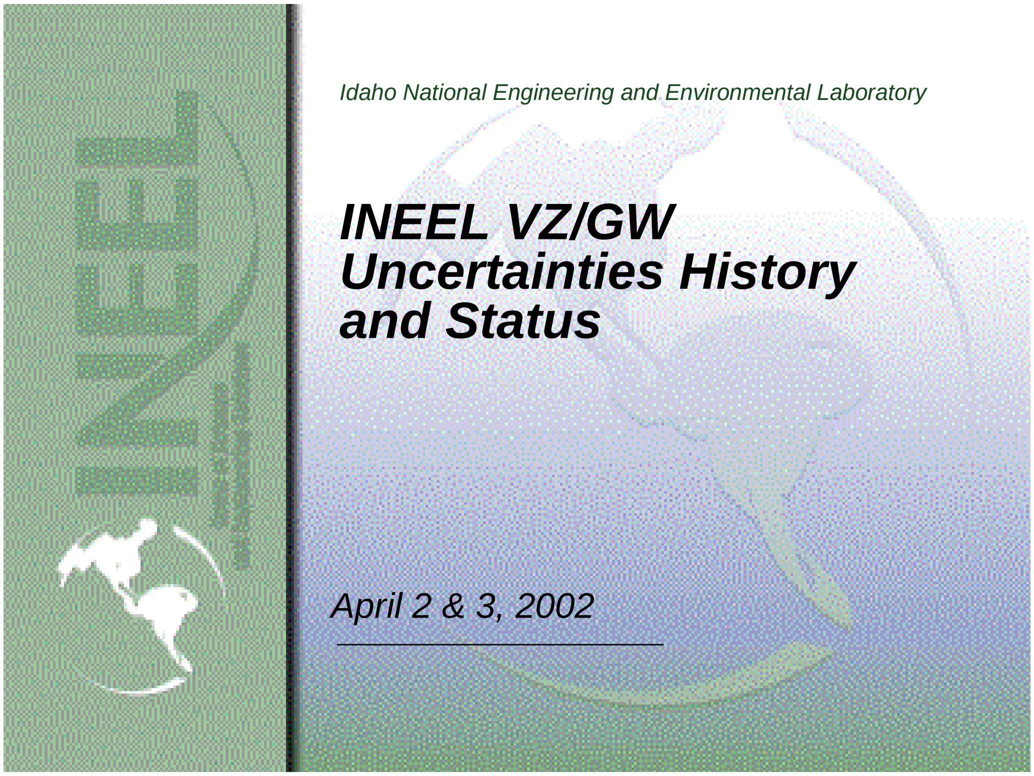
24. Little is known about the effects of hydrothermal variations on flow and transport in the aquifer. (New uncertainty)

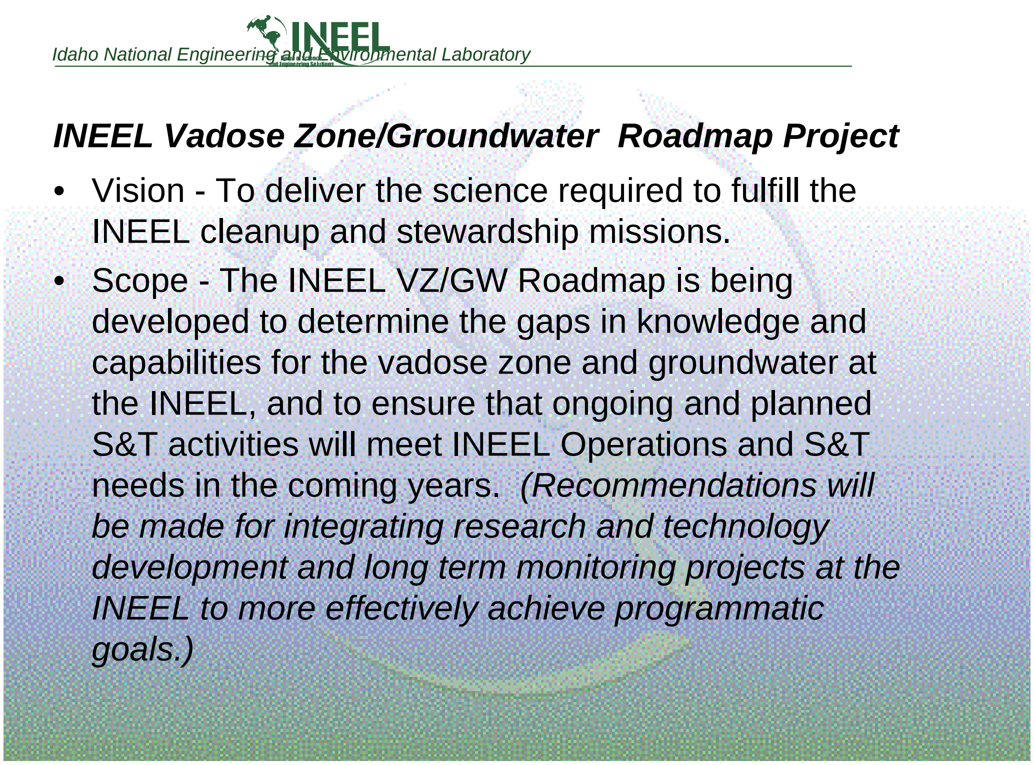
If this is a physical driver for vertical movement or mixing, the conceptual model may have an invalid assumption. {#128}

Even though ranked very low, this mechanism could and probably is significantly influencing the flow regime within the aquifer. {#155}

25. Nonlinear governing equations for multiphase flow requires iterative solution schemes. (technical limitation)

INEEL VZ/GW Uncertainties History and Status





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History of Uncertainties Development

- **Fall, 1998 - Survey conducted to define specific capabilities and needs in the area of vadose zone activities and the INEEL.**
- **March, 1999 - Vadose Zone Program Development Plan**
- **Fall, 1999 - Draft *"Deficiencies in Vadose Zone Understanding at the INEEL"* document prepared.**
- **October, 1999 - Vadose Zone workshop to:**
  - **validate deficiencies**
  - **reduce number (went from 100 to 26)**
  - **regroup deficiencies**

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History of Uncertainties Development (cont.)

- **April, 2000 - Held meetings with Hanford GW/VZ Roadmapping Staff to discuss areas of research needs.**
- **August, 2000 - Finalized *"Deficiencies in Vadose Zone Understanding at the INEEL"* document.**
- **April, 2001 - Developed draft *"Uncertain Predictions of Contaminant Behavior at INEEL: a Roadmap for Addressing Current Limitations through Vadose Zone Studies"* document.**
- **August, 2001- ASME Expert Peer Review of document and project.**

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History of Uncertainties Development (cont.)

- **January, 2002 - Kickoff of Water Integration Project.**
- **March, 2002 - Uncertainties Verification Meeting.**
- **April, 2002 - Uncertainties Prioritization Value Engineering workshop.**

Elements of Good Criteria

Good criteria should

- Be limited to the meaningful and significant few (e.g. 4-8 in number)
- Be as measurable as possible
- Be mutually exclusive
- Discriminate between the choices
- Are driven by the goal
- Focus on the ends and not the means